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THE PRINCIPAL GENETIC TYPES OF SOIL IN CHINA AND THEIR GEOGRAPHIC DISTRIBUTION

I. P. Gerasimov, *Institute of Geography, Academy of Sciences, USSR*

In the summer of 1955 the author of the present article, as a member of a delegation from the Academy of Sciences of the USSR, made a two-month trip to the Chinese People's Republic. During this period a number of field trips were made to different sections of the country. Among the purposes of the field trips was familiarization with the most characteristic of the special features of nature in China. Special attention was devoted to the soils of this country.

One of the important results of this trip was also participation in producing a new soil map of the Chinese People's Republic at a scale of 1:4,000,000.[1] This map was assembled on the basis of earlier soil-cartographic materials. A preliminary draft, in the form of a hand-drawn outline at a scale of 1:4,000,000, was produced by the soil scientist Ma Yun-chzhi. This outline was supplemented in quality and quantity on the basis of field observations made in 1955 by Ma Yun-chzhi and the author of this article.

A considerably reduced and generalized sketch of the new soil map of the Chinese People's Republic, in the form of an outline of the geographic distribution of the principal genetic types of soils of China, is included in the present article. According to this sketch, the following genetic types of soils are found within the territory of the Chinese People's Republic:

- Peat-gley soils
- Gray forest soils
- Chernozems:
  - podzolized
  - leached
  - typical
  - carbonate
- Meadow chernozems
- Chestnut soils
- Brown desert-steppe soils
- Gray-brown desert soils
- Sierozems:
  - cinnamon-brown soils
  - leached
  - typical
- Cinnamon-brown primitive gley and carbonate-gley soils
- Gray cinnamon-brown soils
- Yellow cinnamon-brown soils
- Zheltozems and krasnozems
- Lateritic soils and laterites
- Iron lateritic and lateritic soils
- Meadow-bog soils
- Solonetzes and solonchaks
- Alluvial soils
- Gleyed soils (rice):
  - leached
  - neutral
  - acid
- Mountain meadow soils
- Mountain podzolic soils
- Mountain brown forest soils
- Mountain gray-brown soils
- Mountain chernozems
- Mountain krasnozems and zheltozems
- Mountain and high-mountain (cold) steppe soils
- High-mountain (cold) desert soils

The text of the present article contains a clarification of some of these subdivisions and a general analysis of the new soil map of China.

Characterization of Genetic Soil Types

Peat-gley Soils of Northeast China. This term defines the unique dark-colored neutral and acid soils with constant indications of gleying which are scattered in northeastern China on the alluvial-lake plains of the Sungara and Ussuri rivers and of Lake Khanka. Very often such soils are called by the vague term "meadow" soils. From the genetic point of view a more precise definition is obviously that given above. Incidentally these soils have been subjected to a special detailed study, the results of which have not yet been published. It is highly probable that it will further refine the genetic interpretation of these soils.

Chernozems, Meadow-chernozem Soils, and Solonchak-solonetz complexes on the Dombeya Plains. At the time of the field trips

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[1] An outline copy of this soil map of the Chinese People's Republic, at a scale of 1:18,000,000, was printed in 1957 as Nos. 15–16 in a new geographic atlas published by the Ditu Chuban'she Press. The journal, Kesyu Etunbao, No. 11, 1957, printed an article by Ma Yun-chzhi, "A brief clarification of the new soil map of China," with which I fully agree.

TABLE 1

Analytical data on low-humus chernozem from the Dombeya[a].

Depth of sample, cm.	Humus, %	CO_2, %	pH		Exchangeable cations in me.			Content of particles 0.001 mm., %
			Water	Salt	Ca	Mg	Na	
0–10	2.14	0.16	7.78	7.15	16.22	3.26	traces	15.47
10–20	2.51	0.42	7.54	6.84	17.67	3.33	"	15.92
30–40	2.13	0.04	7.64	6.68	21.32	3.58	"	20.49
50–60	1.46	5.09	8.08	7.15	15.59	2.19	"	17.67
80–90	0.78	6.04	7.99	7.23	16.12	1.96	"	20.21
120–130	—	1.15	7.96	7.62	2.37	0.94	"	4.51

[a] The soil was developed on ancient stratified alluvium; flint gravel had been deposited in the lower part.

in the central plains portion of northeast China (Dombeya), the following soil formations were encountered and described: typical low-humus chernozem; carbonate chernozem; meadow-chernozem soils (typical, carbonate and solonetz-solonchak); meadow and meadow-steppe solonetzes; solonchaks and meadow-bog soils.

Shown below are some analytical characteristics illustrating the genetic definitions referred to above[2]:

The analytical data (Table 1) confirm the field morphological evaluation: exhausted, typical low-humus chernozem.

As may be seen from the drawing of the soil map, soils of such a type have a limited distribution in the Dombeya plains, being generally of the same age as the western, very arid portion. Meadow-chernozem is distributed over all the remaining regions of the Dombeya. Having many points of similarity in common with chernozems, meadow-chernozem soils are known to have a number of special features evident primarily in the characteristics of their humus and salts (especially in the distribution and separation of carbonate salts). These soils develop under conditions of considerable excess moisture at the surface (as a result of poor drainage); for this reason it is always possible to see evidence of gleying in their profiles. Further, many meadow-chernozem soils prove to have been solonized and solonetized (to various degrees) and form complicated complexes with solonetzes (Tables 2 and 3).

Gray and Brown Forest Soils of the Foothill Regions of the Dombeya. In the western and central plains regions of the Dombeya chernozems and meadow-chernozem soils are distributed in complexes with salinized soils. In the moister eastern regions they give way to the gray and brown forest soils. The first of these soils was encountered in the region of Harbin, the second in the Mukden region.

It is seen from the data of Table 4 that gray and brown soils are quite different from each other. The gray forest soil has a thick humus layer (up to 0.5 m.), going over into a dense brown illuvial horizon with siliceous powder. Brown forest soil has a thin humus layer (0 to 15 cm.) and a quite pronounced illuvial horizon which goes over gradually into parent material. Thus, both of the soils described here have characteristics of the development of the podzolic process (podzolization), combined in the gray forest soil with the development of peat (that is, the formation of a thick gray humus horizon).

Cinnamon-brown Soils of North China. On the upland plains and hills of north China—around Peking and on the slopes of the Tsin-lin range to the south of the city of Sian—soils were found and described which were related to the types of the cinnamon-brown soils of dry forests and undergrowth. We recall that this designation now includes soils having completely specific characteristics: primarily little humus, a cinnamon-brown color, a medium to dense coarse blocky structure, neutral or alkaline reaction and increased gleying (metamorphic) over the entire soil profile. Before their separation into an independent genetic soil type, the cinnamon-brown soils were combined either with the brown forest soils (leached cinnamon-brown soils) or with the chestnut soils (typical and carbonate cinnamon-brown soils). Below are given some analytical data for sections of typical cinnamon-brown soils taken in the vicinity of the city of Sian (Table 5).

Soils distributed in northern China and indigenous to the northern part of the wide spaces

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[2] All of the analyses given below were carried out in the chemical laboratory of the Division of Geography and Cartography of Soils, V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR, in agreement with the Institute of Geography, Academy of Sciences, USSR, by the following people: N. A. Andreyeva, L. Bulayeva, K. Ya. Dorokhova, L. Zhukova, N. Kamennye, Karayeva-Ignat'yeva, V. Mochalova, G. Rusakova, with the participation and under the direction of Z. G. Il'kovskaya.

TABLE 2

Analytical data on the meadow-chernozem soils of the Dombeya.

Soils	Depth of sample, cm.	Humus, %	CO_2, %	pH		Aqueous Extract				Exchange-able Na, me.	Content of particles 0.001 mm., %
				Water	Salt	Solid residue, %	HCO_3	Cl	SO_4		
							me.				
Typical meadow chernozem	0–9	4.23	—	7.58	6.59	0.078	0.28	0.17	0.08	traces	20.80
	20–30	2.35	none	7.14	5.85	0.055	0.13	0.17	0.02	"	23.00
	50–60	1.31	0.26	7.47	6.83	0.057	0.44	0.23	none	"	21.66
	80–90	—	5.84	8.13	7.21	0.058	0.54	0.11	"	0.26	17.85
	120–130	—	2.95	8.25	7.29	0.057	0.59	0.17	"	0.31	19.21
Carbonate meadow chernozem	0–10	4.74	5.58	8.28	7.12	0.120	0.75	0.42	traces	0.68	25.32
	15–25	3.83	3.81	8.25	7.19	0.122	0.77	0.59	0.08	1.32	25.48
	30–40	1.64	6.87	8.53	7.24	0.161	1.07	0.59	0.08	2.60	25.60
	70–80	0.67	2.98	8.65	7.00	0.123	1.09	0.17	traces	2.14	27.98
	120–130	—	2.95	8.56	7.16	0.140	1.26	0.23	0.08	2.60	29.04

TABLE 3

Analytical data on meadow-steppe solonetz of the Dombeya

Depth of sample, cm.	Humus, %	CO_2, %	pH		Exchange-able cations in me.		Aqueous extract				
			Water	Salt	Absorptive capacity	Na, %	Solid residue	CO_3	CO_3	Cl	SO_4
								in me.			
0–10	1.79	3.43	9.27	8.56	14.55	13.07	0.625	1.66	7.20	1.73	1.73
11–21	1.52	3.37	8.94	7.87	16.39	7.00	0.294	0.62	3.80	0.33	traces
30–40	0.45	5.86	8.46	7.69	9.83	9.90	0.082	none	1.33	0.12	"
95–105	—	1.96	7.76	—	3.94	0.29	0.057	"	1.13	0.14	"

TABLE 4

Analytical data on gray forest and brown forest soils.

Soil	Depth of sample, cm.	Humus, %	CO_2, %	pH		Exchange-able cations in me.		Content of particles 0.001 mm., %
				Water	Salt	Ca	Mg	
Gray forest	0–10	3.85	none	7.22	6.33	25.87	6.05	25.10
	30–40	2.89	"	6.78	5.89	25.95	5.62	27.73
	80–90	1.75	0.04	6.56	5.40	21.68	7.11	29.01
	150–160	—	0.06	6.04	5.32	—	—	23.00
Brown forest	0–10	2.64	none	7.24	6.42	16.88	4.31	18.37
	30–40	0.58	—	6.83	6.68	16.88	6.98	25.26
	50–60	0.58	—	6.64	5.52	17.02	7.43	26.69
	100–110	—	—	6.78	5.25	20.05	7.87	30.85
	150–160	—	—	7.04	5.14	18.58	7.70	30.72

TABLE 5

Analytical data on cinnamon-brown soil from the vicinity of the city of Sian.

Depth of sample, cm.	Humus, %	CO_2, %	pH (water)	Content of particles 0.001 mm., %	Exchangeable cations in me.	
					Ca	Mg
0–10	4.65	0.06	7.91	32.99	27.20	0.48
25–35	0.92	0.06	7.87	41.30	36.23	1.92
45–55	0.83	0.09	7.81	44.86	32.30	0.98
60–70	—	16.43	7.91	26.46	22.67	0.50

of the Chinese lowlands were designated as primitive cinnamon-brown soils. In these soils, as may be seen from some analytical data (Table 6) there are some of the special characteristics of cinnamon-brown soils (especially metamorphic gleying), but such characteristics are not pronounced. The primitiveness of the soils of the Chinese lowlands is related primarily to their low age. These soils have developed on the most recent alluvial deposits, and from time to time and over a very large area (thanks to the flooding of the rivers and from precipitation) they undergo periodic renewal of alluviation. In addition the lowland soils are widely cultivated, often with the use of artificial watering and the construction of irrigation systems. This gives a definite character to the process of soil formation, accounting for the appearance in it of certain unique characteristics.

Although there are certain irregularities in a number of characteristics (CO_2 content, exchangeable cations, clay) caused by the low absolute age of the soils and the action of irregular irrigation, the basic characteristics of the cinnamon-brown soils (gleying, alkaline reaction, loss of water-soluble salts from the upper portions of the soil, and so forth) emerge fairly clearly.

Gray Cinnamon-brown Soils of the Loess Plateau. Within the area of the so-called loess plateau (to the north of the city of Sian) soils have developed which we have designated "gray cinnamon-brown", and which have an appearance similar to that of the soils described by A. N. Rozanov in the Transcaucasus.

As shown by Table 7 the gray cinnamon-brown soils, while they have a number of properties in common with the cinnamon-brown soils (primarily gleying of the soil layers), are distinguished from the cinnamon-brown soils by having a completely different complex of carbonate salts (always present in all the layers of the soil) and a considerably more alkaline reaction. This gives us a basis for separating the gray cinnamon-brown soils into an independent genetic soil type which is similar to the cinnamon-brown soils, but more xeromorphic. The designation of these soils as *gray cinnamon-brown* emphasizes the combination in them of a number of characteristics of cinnamon-brown soils (gleying) with characteristics of sierozems (carbonate profile).

TABLE 6

Analytical data on primitive cinnamon-brown soil from the vicinity of Peking.

Depth of sample, cm.	Humus, %	CO_2, %	pH		Exchangeable cations in me.		Content of particles 0.001 mm., %
			Water	Salt	Ca	Mg	
0–10	0.77	0.87	7.91	7.21	6.72	4.32	12.02
40–50	0.29	0.21	7.77	6.74	11.18	3.40	17.36
80–90	0.22	none	7.83	6.67	15.65	0.97	11.56
140–150	—	"	7.81	6.60	11.64	1.12	7.67
0–7	2.06	"	7.87	6.90	16.9	3.61	13.14
20–30	0.39	"	7.64	6.40	19.0	2.82	19.59
60–70	0.20	0.31	7.69	6.30	19.2	3.28	18.92
150–160	—	0.15	7.76	6.23	12.17	4.03	11.05

TABLE 7

Analytical data on gray cinnamon-brown soil of the loess plateau.

Depth of sample, cm.	Humus, %	CO_2, %	pH		Exchangeable cations in me.		Anions in water extract, in me.			Content of particles 0.001 mm., %
			Water	Salt	Ca	Mg	HCO_3	Cl	SO_4	
0–10	1.15	3.92	8.46	7.69	14.05	0.49	0.86	0.08	0.08	20.99
40–50	0.78	0.65	8.36	7.52	14.86	4.88	0.79	"	0.04	24.70
60–70	0.83	0.18	8.18	7.24	21.12	2.95	0.80	"	0.08	29.09
100–110	0.84	0.69	8.08	7.50	17.03	2.92	0.78	"	"	23.18
200–210	—	8.23	8.11	7.28	11.11	0.97	0.90	"	none	14.32

Yellow Cinnamon-brown Soils of Central China. In the southern part of the Chinese lowland and particularly in the lower reaches of the Yangtze river (in the Nanking region), the natural conditions of soil formation—primarily the climate and the character of the vegetation—are materially different from those in the more northerly regions of China. The soils here have a very unusual character, which provides a basis for isolating them into a special genetic type under the designation of yellow cinnamon-brown soils. As with the term "gray cinnamon-brown" soils, the designation "yellow cinnamon-brown" emphasizes some of the special genetic characteristics of the soils described and their unique position between the cinnamon-brown soils and the zheltozems.

The analytical data given (Table 8) shows clearly enough that the nature of formation of yellow cinnamon-brown soils consists in the processes of metamorphic claying and the initial stages of allithization with a transition in soil reaction from weakly acid to weakly alkaline.

Lateritic Soils and Laterites of South China. In the southernmost regions of China (those of Nanking and Canton), lateritic soils and laterites were encountered and described which were quite different from the krasnozems and zheltozems of the central part of the country. They are all characterized by a strongly and deeply decomposed allithic mineral soil mass of plastic structure having a fine texture and nonuniform splotchy yellow-red coloring. Field observations showed that predominance of yellow hues was most characteristic of soils under forests or having an especially fine texture; but red hues predominated in soils of unforested expanses and in soils of coarser texture. Thus the impression is created that one or another yellow or red color of the soil is closely connected with different aeration of the soil mass and, possibly, with its capacity for absorbing heat. In tropical and subtropical regions, well-warmed and well-

TABLE 8

Analytical data on yellow cinnamon-brown soils.

Soil	Depth of sample, cm.	Humus, %	CO_2, %	pH		Exchangeable cations in me.		Content of particles 0.001 mm., %	HCl extract in me.		
				Water	Salt	Ca	Mg		SiO_2	Al_2O_3	Fe_2O_3
Yellow cinnamon-brown on clay	0–5	3.70	none	6.68	5.18	10.79	5.29	20.83	—	—	—
	10–20	1.84	"	5.51	4.02	8.46	5.16	25.28	—	—	—
	30–40	0.47	"	7.41	6.54	14.21	7.62	31.84	—	—	—
	70–80	0.22	"	6.99	6.05	19.16	9.02	45.85	—	—	—
	150–160	—	0.17	7.50	6.36	26.29	10.31	48.75	—	—	—
Yellow cinnamon-brown on basalt	0–5	3.51	—	6.31	5.15	29.98	15.48	40.51	11.2	138.9	83.8
	5–15	2.76	—	6.39	5.30	30.86	15.46	39.79	4.7	151.3	87.0
	30–40	1.00	—	6.79	5.96	31.67	15.73	34.50	3.7	148.7	90.3
	60–70	0.88	—	6.79	5.98	35.01	17.74	37.45	5.7	175.8	89.3
	90–100	—	—	6.83	6.05	37.38	17.52	28.64	5.0	162.4	87.6

aerated soils for the most part evidently acquire the red coloration; soil profile which are "colder" and less accessible to "aeration" for the most part have the yellow color.

The total thickness of the allithized soil layer in the profiles just described varied considerably. This made it possible to divide the soils of south China into two basic groups: lateritic soils and laterites. By the latter we understand soils having a decomposed layer which is especially thick. The upper layers are very important in lateritic soils and laterites. Under natural forest vegetation and under more or less flat portions of the relief all lateritic soils and laterites are podzolized to some degree. On the other hand, under unforested areas and especially on slopes (under tilled, abandoned, cutover forest land) they are almost always "beheaded" (as a result of washing away) and for this reason have no clear characteristics of podzolization. Thus, field observation has shown that two processes are of principal importance: deep decomposition (allithization) of the soil mass on the one hand, and podzolization developing in the upper part of the soil layer as if superimposed on the laterization process, on the other hand.

TABLE 9

Analytical data on lateritic soils.

Soil	Depth of sample, cm.	Humus, %	pH		Cation exchange capacity, me.	Content of particles 0.001 mm., %	HCl extract in me.		
			Water	Salt			SiO_2	Al_2O_3	Fe_2O_3
Lateritic soil on granites	0–10	1.70	5.92	3.94	4.38	32.01	2.2	48.8	27.0
	20–30	0.87	5.23	3.92	2.97	35.75	2.0	53.3	28.3
	40–50	0.66	5.83	4.09	3.19	25.35	1.3	52.9	30.1
	80–90	0.49	5.90	4.23	3.55	37.22	2.2	51.1	30.4
	120–130	—	5.14	4.23	2.94	24.92	1.3	39.0	34.0
	200–210	—	5.40	3.89	4.21	36.94	2.2	74.6	46.6
	300–310	—	5.76	4.06	4.61	33.14	1.8	48.3	44.0
Lateritic soil on shales	0–10	4.81	5.17	3.49	1.72	30.25	2.4	41.7	13.7
	10–23	1.61	4.94	3.56	1.01	35.38	2.8	49.1	17.4
	23–40	1.06	4.76	3.57	1.11	41.16	2.8	52.5	22.0
	40–60	0.90	4.66	3.66	1.61	46.54	2.0	64.7	23.0
	100–110	0.52	5.67	3.62	0.76	36.34	1.5	44.8	24.7
	135–170	—	5.31	3.73	0.85	26.51	2.2	32.8	24.7

TABLE 10

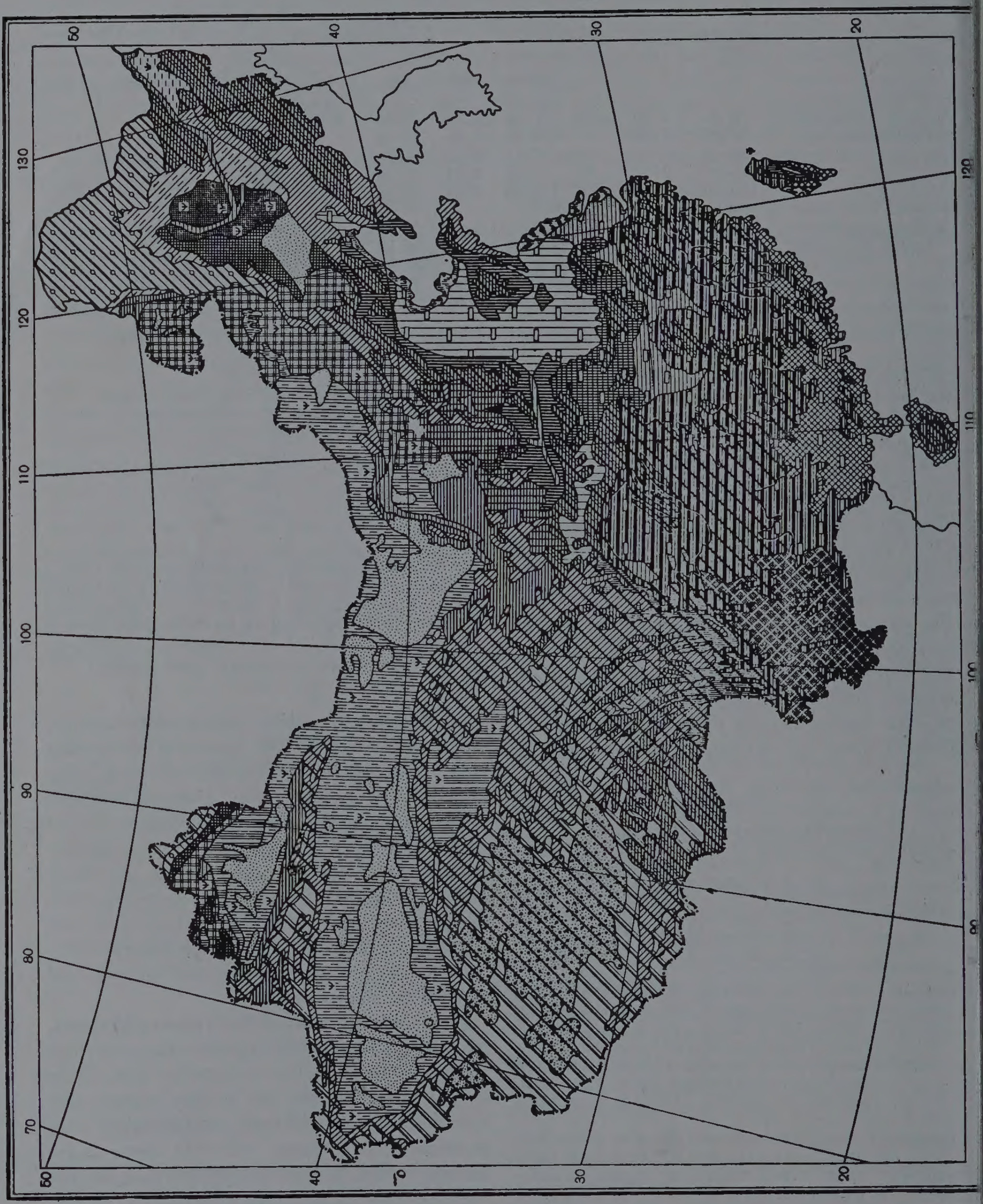
Analytical data on iron-lateritic soils from the vicinity of Kunming[a].

Depth of sample, cm.	Humus, %	pH		Cation exchange capacity, me.	Content of particles 0.001 mm., %	HCl extract in me.		
		Water	Salt			SiO_2	Al_2O_3	Fe_2O_3
0–10	7.80	5.40	4.37	9.04	36.85	6.3	223.4	101.3
10–20	4.20	5.52	3.90	5.18	38.28	14.5	234.4	121.4
30–40	1.53	5.92	4.68	2.23	48.77	8.3	266.6	145.8
120–130	—	6.05	4.72	2.66	54.21	13.2	250.9	141.2

[a] Soil developed on original rock (basalt).

Chemical characterizations of the two soil profiles are shown (Table 9).

Iron-lateritic Soils of the Yunnan Plateau. According to most of their genetic characteristics these soils are similar to the lateritic soils. Their special characteristics are a silty texture and a permanent, clear-red color, fading slightly only in freshly cut sections; it is laid down under natural forests. It may be assumed that the red color of Yunnan soils and their unique texture are caused by the accumulation in them of only slightly hydrated ferric oxides which form thin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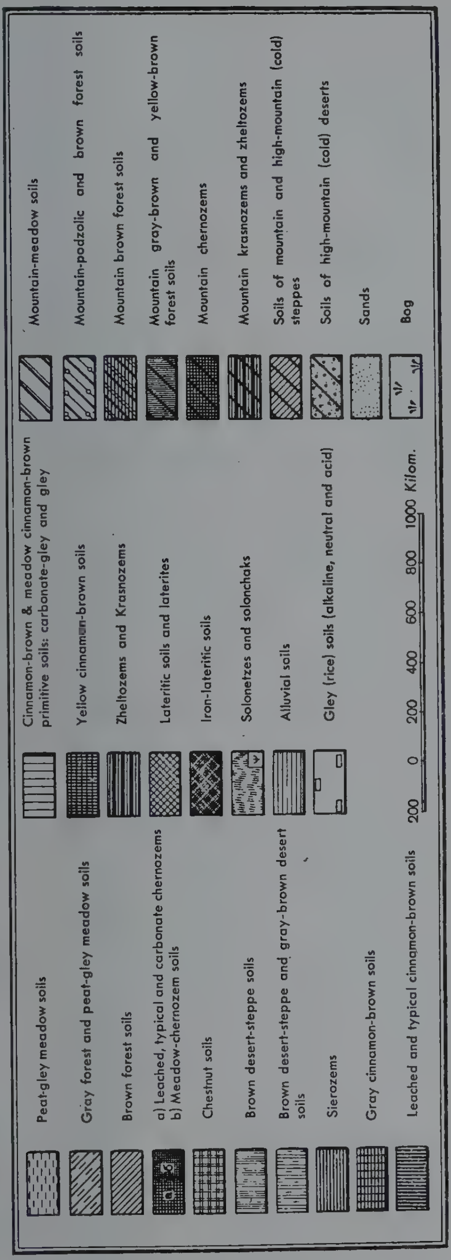
Peat-gley meadow soils
Gray forest and peat-gley meadow soils
Brown forest soils
a) Leached, typical and carbonate chernozems
b) Meadow-chernozem soils
a
b
Chestnut soils
Brown desert-steppe soils
Brown desert-steppe and gray-brown desert soils
Sierozems
Gray cinnamon-brown soils
Leached and typical cinnamon-brown soils
Cinnamon-brown & meadow cinnamon-brown primitive soils: carbonate-gley and gley
Yellow cinnamon-brown soils
Zheltozems and Krasnozems
Lateritic soils and laterites
Iron-lateritic soils
Solonetzes and solonchaks
Alluvial soils
Gley (rice) soils (alkaline, neutral and acid)
200 0 200 400 600 800 1000 Kilom.
Mountain-meadow soils
Mountain-podzolic and brown forest soils
Mountain brown forest soils
Mountain gray-brown and yellow-brown forest soils
Mountain chernozems
Mountain krasnozems and zheltozems
Soils of mountain and high-mountain (cold) steppes
Soils of high-mountain (cold) deserts
Sands
Bog

Soil Map of the Chinese People's Republic.
Scale 1:20,000,000. Composed by I. P. Gerasimov and Ma Yun-chzhi.

films investing soil particles and forming concretions of varying dimensions. If this assumption is correct, then it is just this unique quality of the soils described that distinguishes them from typical lateritic soils. In the latter there are always present, in addition to the alumina, free hydrated ferric oxides (often in fairly large quantities), but here they are not fixed (at least in the upper soil horizons) in the form of ferrous crusts or concretions, but migrate freely (together with the alumina) being retained in different portions of the lateritic profile. In iron-lateritic soils such free migration of the hydrates of ferric oxide evidently does not take place throughout the entire profile. Under the action of the strong warming during the dry season, these iron compounds become dehydrated in the upper layer of the soils, lose their mobility and form tough films around the soil aggregates. With the passage of time the thickness and mass of such iron accumulations increase and a characteristic formation of dense ferric crusts and shells occurs on the older elements of the surface. The analytical data for these soils is shown in Table 10.

Regular Geographic Patterns

In 1954 an article by the Chinese geographer Lo Kai-fu entitled "A Project for the Division of China into Natural Regions" was published in the Chinese geographical journal "Dili Syuebao" (Vol. 20, No. 4). This article, as the author notes, is the result of a large amount of collective labor undertaken by the geographers of China during the last few years for the establishment of natural (that is, natural-history) regions for the territory of China. On the basis of this work, and also of the field observations cited above and of general consideration of the new soil map of the Chinese People's Republic (a sketch of which is located in this paper) it appears to be possible to characterize the principal regular geographical patterns of the soils within China.

All seven of the large natural regions into which China is divided by geographers have clear geographical-soil differences.

Northeast China. This region is characterized by the development in the central plains portion of complicated steppe complexes of chernozems and of meadow-chernozem and solonetz-solonchak soils which were described at the beginning of this paper. The central plain of the Dombeya is surrounded, in the north and east by a foothill-forest-steppe belt of gray and brown forest podzolized soils with peat gleyed soils; this is replaced to the south (in the vicinity of Mukden) by brown forest soils and leached cinnamon-brown soils. In the western part of the Dombeya the steppe soils of the central plain gradually go over into soils of the mountain steppes and of the meadow steppe of the Great Khingan mountains. A similar association of soil types in the area of northeast China corresponds fully to the dominance here of arid continental climatic conditions of the temperate zone.

In northern China four principal groups of soils predominate in the makeup of the soil cover: in all mountainous regions (Lyaodun, Shan'dun, Taikhan'shan, etc.) brown forest soils have developed; in the region of the foothills (that is, near Peking, on the northern slope of Tsin'lin) there are cinnamon-brown soils of various subtypes; on the north Chinese plain there are unique ancient alluvial cinnamon-brown and meadow cinnamon-brown soils of primitive structure which show the effects of prolonged agricultural use; there are also separate large areas of gleyed (rice) and alluvial meadow soils. On the loess plateau of northern China there have developed some unique soils which have for the most part been deeply tilled and which we designated gray cinnamon-brown soils.

It is known that the climatic conditions of northern China have a continental character with temperate-cold dry winters and hot moderately dry summers. And although the seasons here differ materially from conditions in the dry subtropical countries of the Mediterranean type, for which the specially widely distributed cinnamon-brown soils are characteristic, nevertheless the general traits of the precipitation and temperature conditions of the soils are evidently quite similar: this makes it possible to classify north China as an area of dry subtropical conditions.

Central China. Here the soil has an especially complex structure. In the northern part, on the lowland plains, large areas of primitive cinnamon-brown and meadow cinnamon-brown soils without carbonates have developed, as well as gley and alluvial-meadow soils, which in the area of the lower reaches of the Yangtse river go over into unique yellow-brown soils. Further south, along with large areas of gleyed rice soils (chiefly acid and neutral), various zheltozems and krasnozems have acquired wide development, both on the plains and in the mountains. They are often eroded and developed on old, weathered allithic crust. Large areas of strongly eroded zheltozems and krasnozems are indigenous to the so-called Red (Sychuan) basin. Thus, with respect to the composition of its soil types the area of central China, as distinguished from that of northern China, may be related to the moist subtropics.

Southern China. These soils have acquired a strongly pronounced allithic character. Here in the entire eastern part of the area lateritic soils predominate grading, in the southernmost parts, into more or less typical laterites. Only in the western portion of southern China on the Yunnan plateau does the degree of allithization of the present soils become weaker. Here some unique iron-lateritic soils have developed on the old and weathered allithic crust. In southern China there are also many gleyed rice soils of an acid character.

The iron laterites of the Yunnan plateau extend across the border of the Sikang-Yunnan region. The composition of the soil types of this region is not yet fully clear to us. The field trip of 1955 did not touch its territory and the soil map has here, to a certain degree, a hypothetical nature. Evidently on the slopes of the mountain valleys of the north-south mountains special mountain-forest soils of a subtropical nature have developed (they are called yellow-brown and gray-brown forest soils), while in the more elevated areas there are probably brown forest soils. Evidently mountain-meadow soils and soils of high-mountain steppes have also developed on the more or less pronounced mountain watersheds in this part of the area.

Tsinghai-Tibet Region. In this enormous region which occupies the entire southwest portion of the territory of the Chinese People's Republic, the following groups of soils have wide but very complex distribution which has as yet not been studied in any detail: soils of high-mountain (cold) steppes and deserts and mountain-meadow soils.

Mongol-Sin'tszyan Region. In this region the soil is also quite variegated which points out the necessity for further subclassifying this territory. In addition to the soils of sandy, stony and clayey deserts (gray-brown desert soils, lime-gypsum crusts) desert-steppe soils (brown soils) have developed here, as well as those of dry steppes (chestnut soils). The soils in the vertical belts of mountains are also quite variable. In the extreme western and eastern portions of the region—on the border between the USSR and north China—there are apparently isolated large areas of sierozems (on loess), and the mountain and high-mountain meadow-steppe and steppe soils have broader development at almost all mountain elevations. In a number of places in the west there are dark-colored forest soils (under evergreen forests), mountain-meadow, and other soils.

Comparison of the regional differences considered above in the composition of the soils of China makes it possible to outline the principal regular soil-geographical patterns. In the Chinese People's Republic as in all other vast portions of the earth's surface, the most general geographic peculiarities in the structure of the soils reflect, primarily, the three most universal world patterns: latitudinal or horizontal zonality; facies or provinciality; and vertical zonality.

Latitudinal, or horizontal zonality is manifested in China by the regular replacement of genetic types of soils which are native to the north-temperate (boreal) geographical zone and which are distributed in northeastern China (gray forest soils, chernozems, chestnut soils, etc.) by types of soils native to the dry and the moist subtropics in northern and central China (cinnamon-brown and yellow cinnamon-brown soils, krasnozems and zheltozems) and, further south, by the genetic types of subtropical soils (lateritic soils and laterites in southern China).

Facies or provinciality of soils, which reflect geographical soil changes related to local peculiarities of the bioclimatic setting of soil formation, has no less distinct development in China being intimately interwoven with latitudinal zonality. On the whole it is manifested in the replacement of the more humid ("oceanic," maritime) types of soils distributed in the eastern border portion of the country by increasingly arid ("continental") types distributed in the western, profoundly continental portion. Such, for example, is the replacement of brown forest and cinnamon-brown soils by gray cinnamon-brown soils and sierozems in the zone of northern (central) China or the replacement of the typical lateritic soils of southeastern China by the iron laterites of the Yunnan plateau, and so forth.

Finally, vertical zonality has important and variable reflections in the Chinese People's Republic. Being subordinated to the first two more general patterns, vertical soil zonality develops in different forms in different latitudinal zones and soil facets (provinces). As a consequence of this there are in various parts of China quite different structures in vertical soil zones which, incidentally, may serve as a reliable basis for the physico-geographical division of mountainous areas into regions.

In summary, the territory of the Chinese People's Republic has soils of variable composition and very complex structure. Actually, although it has a considerably smaller total area than the USSR, China almost exceeds the Soviet Union in the variety of its soils. It is true that the more southerly location of the territory of the Chinese People's Republic accounts for the more limited distribution in China of soils of the north-temperate zone which are more characteristic of the USSR, for example the podzolic and bog soils of the taiga and the chernozems and chestnut soils of the steppes and others. In China the soils which are native to the subtropical and tropical zones are more variable. A very large part of this country, almost all of central and southern China, is located in a humid subtropical and tropical environment. For this reason in China we regularly encounter a whole gamut of different soil types of a similar character. These include yellow cinnamon-brown soils, krasnozems and zheltozems, lateritic soils and laterites, iron laterites, and certain others. Furthermore, for a considerable portion of its area the territory of the Chinese People's Republic lies at a high altitude and has discontinuous mountain relief. For this reason in addition to the genetic types of soils enumerated above, the formation takes place on the subtropical Chinese plains of special combinations of soils and soil types under conditions of vertical geographical zonality of the subtropical zone. They are related, for example, to the yellow-brown and gray-brown mountain-forest soils mentioned above and also to the unique genetic types of soils of the high-mountain cold deserts and steppes of Tibet. Unfortunately, it cannot be said that we already know enough about the genetic peculiarities of all these unique types of soils of China. On the contrary, it is only in recent years and through the work of modern Chinese soil scientists that light has been shed on the existence of similar soil formations and the necessity of distinguishing them from the mountain-forest soils of the north temperate zone or the desert and steppe soils of the plains which were described earlier.

It is known that the scientific bases of modern soil science were developed in the second half of the nineteenth century in the works of V. V. Dokuchayev and his collaborators by a geographical study of soils, chiefly in the European portion of Russia. These soils—chernozems, podzolic, chestnut soils and others—are widespread in the European portion of the USSR and are very typical for conditions of the north temperate zone. It is on the basis of such investigations that many of the general theoretical theses of soil science were established and there was resourceful discovery of the genesis of a number of important types of soils.

It is further known that the genetic depth and geographic breadth of Dokuchayev's ideas were rightly esteemed in world science. His principles are the basis of the modern scientific theory of soil science while his methods of the geographic and genetic study of Russian soils have become classic. In the area of the Soviet Union his methods could unfortunately not be applied on the proper scale to the study of subtropical soils. Conditions are quite different in this respect in China. Therefore, there is every reason to expect that a rapid rise, so characteristic of the modern period, in the development of soil science in China will have important and promising consequences. Scientific investigations in China of the geography and genesis of the subtropical soils of the plains and mountains will be especially important. They will doubtless reveal many new and important phenomena and aspects of subtropical soil formation and will thus enrich the scientific theory of soil science.

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SOIL RECLAMATION ON THE GOLODNAYA STEPPE

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The intermountain plain at the middle course of the Syr-Dar'ya river, having the form of a gigantic triangle with an area of about 1,000,000 hectares, bears the geographical designation "Golodnaya Steppe."[1] On the south it is bounded by the Turkestan range, on the north and northeast by the Syr-Dar'ya river and on the west by the Kyzyl-Kum sands (Fig. 1).

The steppe received this designation evidently because travellers following the Tashkent-Samarkand caravan trade route were obliged, between the Syr-Dar'ya river and the town of Dzhizak, to survive a waterless expanse stretching more than a hundred kilometers in a straight line. For this distance they had to carry with them food, forage and even water for both themselves and the animals on which they were making the trip.

From time immemorial human beings have been trying in vain to revive this expanse and to create in it a flourishing oasis such as were found nearby in the Chirchik, Fergana and Zeravshan valleys. Many legends have been composed around the idea of a revival of the lands of the Golodnaya Steppe. The most poetic of them is the poem by Alisher Navoi; "Farkhad and Shirin." Along the flood-plain portions of the Syr-Dar'ya river, irrigation of tiny and scattered areas actually existed in ancient times.

The development of regular irrigation on the Golodnaya Steppe begins at the end of the nineteenth century. The first irrigation projects here were begun and finished in the period 1890 to 1895. At this time the canal called at first the "Khivinskii aryk" and later "Nikolai I" was built. In 1900 approval was obtained for the engineering project of the Golodnaya Steppe canal into which the Nikolai I canal was to be incorporated. This project was to irrigate 50,000 hectares of new land but was changed and supplemented many times. Its construction was completed in 1913.

A period of intensive reconstruction and creation began to develop with the advent of Soviet authority in all fields of economic life. As early as May 17, 1918, V. I. Lenin signed a decree for the "irrigation of 500,000 desyatinas[2] of the Golodnaya Steppe of the Khodzhent region, Samarkand district, and for the provision of the principal structures of an irrigation system encompassing an area of 40,000 desyatinas[3] of the Dal'verzin Steppe." For a number of reasons Lenin's decree was not fulfilled. However, during the Soviet period the Golodnaya Steppe canal (now called the Kirov Magistral canal) was considerably lengthened and widened. At present it irrigates an area of over 200,000 hectares in Uzbekistan and Kazakhstan. After construction had been finished on the Farkhad dam and the Kaira-Kum reservoir on the Syr-Dar'ya river, a possibility appeared for the further development of irrigation on the Golodnaya Steppe. A decree of the Central Committee of the Communist Party of the Soviet Union and of the Council of Ministers of the USSR (No. 1059, Aug. 5, 1956) envisages supplementary irrigation on the Golodnaya Steppe of 300,000 hectares of new land, of which 200,000 hectares are in the Uzbek Soviet Socialist Republic and 100,000 in the Kazakh Soviet Socialist Republic.

The fundamental cause of the centuries-long failure to irrigate the Golodnaya Steppe is found in natural conditions there. In its upper part the Golodnaya Steppe plateau is separated from the Syr-Dar'ya river by a high, steep bank ("kiyat") of 20 meters or higher. This condition made it extremely difficult to divert the water under its own flow. Moreover, in those days there was neither the means, know-how, nor social climate for the organization of the mechanical delivery of the water or the construction of a dam.

Hydrogeological Conditions

The intermountain depression of the Golodnaya Steppe has been filled with alluvial-proluvial sediment of rivers and streams flowing in this direction from the Chatkal mountains, the Turkestan range, and the Syr-Dar'ya river. Judging by a number of test drillings going down 1250 m., these deposits reach hundreds of meters in depth. It is assumed that they are underlain

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[1] Literally, "Hungry Steppe"—Translation.

[2] 1,350,000 acres—Translation.

[3] 108,000 acres—Translation.

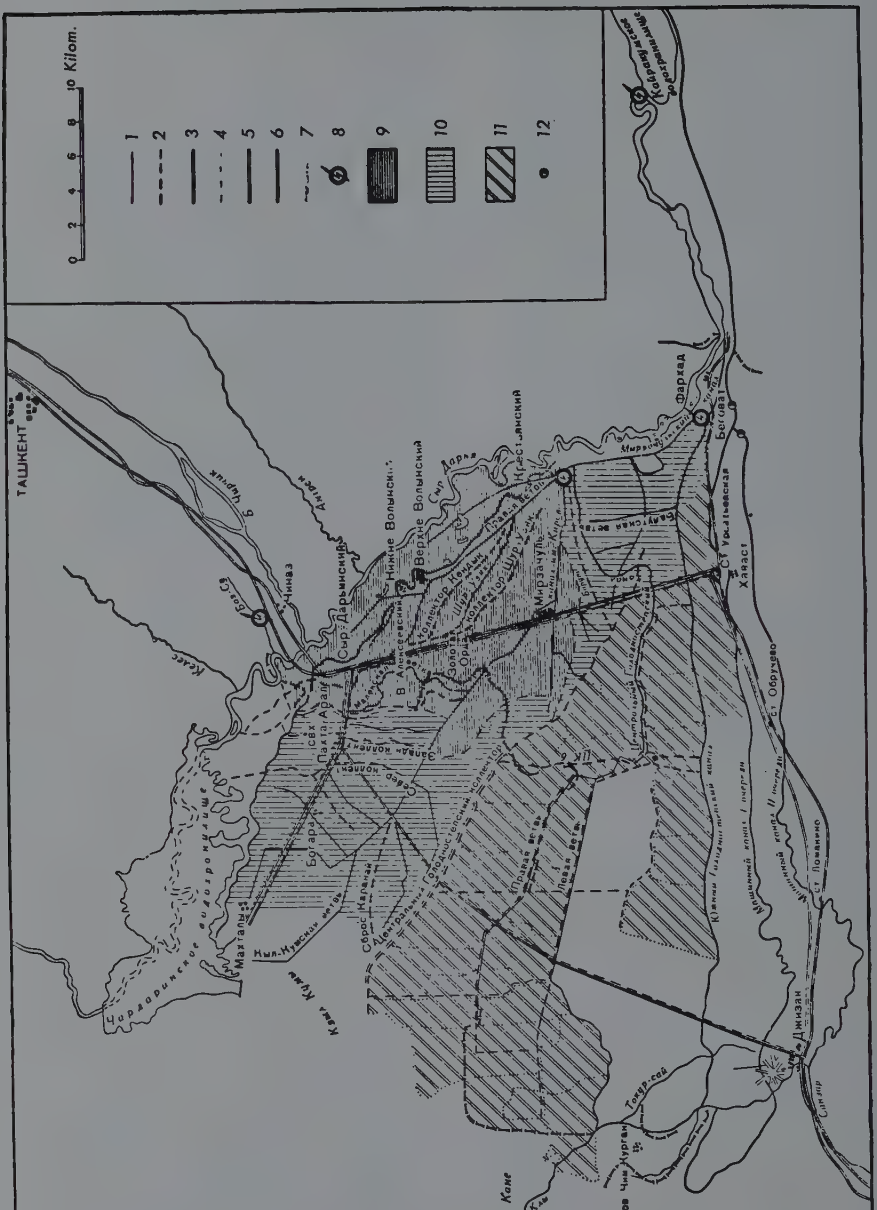

FIG. 1.—Diagram of the development of irrigation on the Golodnaya Steppe. 1—Irrigation canals; 2—Collecting drainage ditches; 3—Existing highways; 4—Highways under construction; 5—Existing railroad lines; 6—Railroad lines under construction; 7—State farm boundaries; 8—Hydroelectric station; 9—Land partially reclaimed before the 1917 revolution; 10—Land reclaimed after the 1917 revolution; 11—Land being reclaimed; 12—Pumping stations.

by deposits of the Older Tertiary ("Paleogenic") and the Cretaceous which are exposed on the piedmont of the Chatkal and Talas mountains. In the southern part of the syncline such exposure is not apparent.

The old, coarser deposits are covered above by fine-textured Quaternary soil. The thickness of the fine-textured soil layer in the region of the Syr-Dar'ya river reaches three to five meters, and further south and west of this it increases to 20 to 40 m. and more. Under the deposits of fine-textured soil lie sandy and sandy-gravelly stone, deposits which are interrupted in places by lenses of clay or clay loam. Judging by geological structure the lower and upper water-bearing strata represent a single unit and changes in one stratum are inevitably reflected in the other, as shown by observations on the dynamics of the ground-water levels in wells of different depths (3 to 70 m.).

The thicker gravelly deposits on the Golodnaya Steppe were evidently produced by the Syr-Dar'ya river on its emergence from the Fergana valley, where drillings 300 meters in depth made in 1956 by the Grasslands Improvement Trust failed to disclose the underlying rock. A drilling 458 meters in depth made by the same Trust in the Bayaut region also failed to show the underlying later Tertiary ("Neogene") rock of the Golodnaya Steppe.

The drilled shafts in the Shuruzyak depression reveal under a fine-textured layer, a gravelly-stone layer, which begins at a depth of 30 to 40 m. and goes down to 100 to 200 m. and deeper. The observed thickness of the Chirchik-Angren alluvial deposits reaches 300 m. and more along a front of more than 70 km. The permeability coefficient of these coarse deposits varies from 170 to 1400 meters per day.

The general sources of supply of subsurface water on the Golodnaya Steppe are as follows: from the south, surface and subsurface flow from the Turkestan mountains; from the north, subsurface flow from the Chatkal mountains and surface and subsurface flow from the Syr-Dar'ya river. The basic water-bearing layer for the subsurface flow is the old gravel-stone deposits.

Determination of the quantity of subsurface water arriving from each of the sources enumerated is extremely difficult and complicated. However, judging by the permeability coefficient, the slope of the water table, and the approximate thickness of the aquifer, it may be assumed that the subsurface water reaches the Golodnaya Steppe from the Chatkal mountains in quantities five to six times as large as those from the Turkestan range. According to my own observations the total quantity of subsurface water arriving in the area of the Golodnaya Steppe during one year averages 2,500 to 4,000 cubic meters per hectare. More water reaches the eastern part than reaches the western part. The Syr-Dar'ya river, as a result of its very slight gradient and because of the vastness of the Golodnaya Steppe, may be said to drain the Steppe only near its banks. A very small portion of the flow of water away from the Golodnaya Steppe takes place in a westerly direction toward Kyzyl-Kum and a depression at the place called "Tuzkane." Following construction of the Chardarin reservoir on the Syr-Dar'ya the outflow of ground water from the Golodnaya Steppe plateau is becoming worse and conditions for soil improvement far more complicated.

Most of the subsurface and surface water reaching the Steppe formerly went and now still goes into evapotranspiration.

On the basis of existing data from investigations and observations, we came to the conclusion that all of the subsurface water of the Goladnaya Steppe is under pressure. The hydrodynamic pressure is most clearly manifested in the sand-gravel-stone deposits of the deep layers which sometimes reach a hundred meters or more. A flowing well 116 m. deep near the village of Krupskaya has an output of 10 liters per second and a pressure head of 5 m. above the earth's surface. Shallow wells sunk into the clay loam of the Shuruzyak depression showed pressure heads of 0.3 to 1.2 m., depending on the well depth and texture of the material.

The average value of the permeability coefficient of the silty clay loams of the Golodnaya Steppe, as determined by the method of evacuation (pumping out), is 0.28 meters per day with fluctuations from 0.005 to 1.540 m. per day. For depressed areas of the relief, such as the Sardobin depression, the average permeability coefficient is 0.03 meters per day. The average value of the permeability coefficient as determined in the laboratory by Tim-Kamenskii apparatus varied within the following limits: for fine-textured sand 1.5 to 3.0; for medium-textured sand, 1.5 to 5.5; and for gravel, 70 to 86 meters per day. It must be noted that the permeability coefficient determined by the laboratory method often fails to correspond to reality. For example a drilled well 55 m. deep in Verkhne-Volinskii district with a zone of saturation consisting mostly of thin- and fine-textured sands showed, on evacuation, a depression of 11 m., but it delivered 55 liters per second and its radius of influence was 400 m.

Starting from the obtained values of the parameters the permeability coefficient, calculated by the formula

$$K = \frac{Q \log \frac{R}{r}}{1.36(H^2 - h^2)}$$

was 17.3 meters per day, where H is the thickness of the aquifer and h is the depth of the location of the strainer (filter) in meters. The permeability coefficient for coarse materials in the village of Soldatskii area, determined by the same method, was 138 meters per day. From these data it is evident that the coefficient of permeability determined by the laboratory method is less than that obtained under actual field conditions.

As a result of special geological features of the structure of the Golodnaya Steppe and its hydrogeological conditions, the subsurface water which is furnished continuously via the aquifer is transferred by a certain hydrodynamic pressure to the upper horizons of the soil. Evaporating from these upper horizons during the course of whole geological periods, this water left behind the salts which it had brought with it in the places where it had evaporated. This is the basic cause of the fact that over almost the entire Golodnaya Steppe, no matter at what depth the ground water might be, the surface horizons have been salinized and in varying degree soil in the capillary fringe has been salinized.

TABLE 1

Salinization in grams per liter of subsurface water along the profile of one of the drillings of the Golodnaya Steppe.

Depth from which water sample taken, meters	Solid residue	Cl^-	$SO_4^=$	$CaCO_3$	$CaSO_4$	$MgSO_4$	Na_2SO_4	NaCl	Mineral residue
1.8	14.72	4.88	3.83	0.201	2.04	3.13	0.94	8.04	13.56
3.8	13.82	4.56	3.67	0.149	2.51	2.48	0.92	7.52	12.50
5.6	13.06	4.31	3.49	0.056	3.06	1.84	0.80	7.11	11.84
13.0	12.54	4.67	3.05	0.020	2.11	1.64	0.22	7.70	11.42
20.5	9.24	2.50	2.88	0.112	2.01	1.58	1.13	4.12	8.34
37.0	2.57	0.74	0.64	0.025	1.07	0.02	0.52	0.58	2.31
65.8	6.79	1.28	2.41	0.025	1.91	1.31	0.73	2.11	6.23

TABLE 2

Salinization in grams per liter of subsurface water from drillings 5 and 6932, and from the Syr-Dar'ya and Chirchik rivers.

Place from which water sample taken—river and station	Solid residue	Cl^-	$SO_4^=$	HCO_3^-	Ca^{++}	Mg^{++}	$K^+ + Na^+$
Drilling 5	0.510	0.206	0.213	0.085	0.064	0.020	0.189
Drilling 6932	0.424	0.014	0.115	0.280	0.096	0.025	0.012
Syr-Dar'ya (Zaporozhe)	—	0.033	0.096	0.174	0.060	0.021	0.047
Syr-Dar'ya (Chardarin)	—	0.020	0.075	0.163	0.051	0.016	0.033
Chirchik (Chinaz)	0.259	0.007	0.013	0.159	0.042	0.011	0.018

The salinization of ground water is not uniform along the profile. The upper horizons of the ground water from which evapotranspiration continuously takes place are more salinized. The lower horizons of ground water, corresponding to levels having an increased permeability coefficient (stones, gravel, sand) governing the relative speed with which the flow of subsurface and ground water takes place, have the least salinization and are sometimes no different from the water of the Syr-Dar'ya, Chirchik, or Sanzar rivers (Table 3). The salinization of the ground water between the two limiting levels, that is, the level of the ground water and the aquifer through which the flow of ground water takes place, has an intermediate value (Table 1).

In the example shown, the ground water with the lowest salinization corresponds to a depth of 34 to 37 m., that is, to the stratum having the greatest permeability. It must be noted that there is a certain regularity in the distribution of the anions along the ground water profile. The most mobile elements, for instance, chlorine, are concentrated in the upper layers of the soil, while $SO_4^=$ is distributed more regularly along the profile.

Drillings 5 and 6932 and many others supplied from the sand-gravel-stone aquifer (Table 2) can serve as proof of the fact that in soil zones with distinctively high permeability and thus a higher rate of exchange of water, salinization is negligible.

Salinization of the subsurface water, even with prolonged evacuation of the aquifer, remains relatively unchanged. For example, when drilling 6 was pumped out continuously for nine months, the salt content changed from 2.6 to 2.8 grams per liter of solid residue. With respect to area, salt content of the subsurface water of the Golodnaya Steppe is extremely variable, both in quantity and in composition of the salts.

On the first flood-plain terrace, the least salt content corresponds to the narrow belt of land extending along the bank of the Syr-Dar'ya river. The salt content increases with increasing distance from the bank and, in places, reaches 25 to 27 grams per liter of solid residue. The mean salt content of the ground water of the whole terrace area amounts to 5.7 grams per liter of solid residue. The area with a salt content of 3.0 to 11.0 grams per liter predominates. The salts are composed generally of sulfate, chloride, sodium, potassium and magnesium.

The second terrace above the flood plain is divided into two subareas with ground water of differing salt concentrations: the Shuruzyak depression with a mean salt content of about 10 grams per liter, and the level portion of the terrace with a mean salt content of 4.4 grams per liter of solid residue. As a rule the salt content of ground water is higher on undrained areas, while in drained areas adjoining a constant source of water it is lower—from 2 to 8 grams per liter of solid residue. In the Shuruzyak depression the salts of the ground water consist of sulfate, chloride, sodium, potassium and magnesium.

On the third terrace above the flood plain the salt content of the ground water is extremely variable and ranges from 0.6 or 0.7 to 47 or 48 grams per liter of solid residue. The mean salt content of the entire terrace is 13.5 grams per liter of solid residue. The smallest salt content, up to 1 gram per liter, is associated with a belt 5 to 20 m. wide going along the bank of a big canal which is always full. A salt content of more than 3 grams per liter of solid residue predominates over most of the area.

TABLE 3

Distribution of areas having different salt concentrations in ground water on the Golodnaya Steppe.

Area	Percent of the area having ground water of different salt concentrations, in grams per liter						
	< 1.0	1.0–3.0	3.0–5.0	5.0–10.0	10.0–20.0	>20.0	Total
First terrace above flood plain	15.5	14.4	25.9	34.6	7.2	2.4	100
Second terrace above flood plain:							
a) Shuruzyak depression	—	2.1	7.5	58.3	27.8	4.3	100
b) Level area	7.6	27.2	41.4	20.6	2.6	0.6	100
Third terrace above flood plain	3.4	13.2	21.9	21.2	15.5	24.8	100
Sardobinsk depression	0.3	—	1.2	15.4	54.6	28.5	100

The highest concentration of salt is found in the ground water of the Sardobinsk depression. The mean salt content at the bottom of the depression reaches 36.2 grams per liter of solid residue. In a belt up to one kilometer from a constantly active canal, the salt content at the water table is higher than 5 to 7 grams per liter, but at increasing distances away it increases to as high as 30 to 40 grams per liter of solid residue. That portion of the area with a salt content of less than 5 grams per liter in the ground water amounts to less than 2% of the entire area of the depression.

The salts encountered in the upper layers of the ground water contain chloride, sulfate, sodium, potassium, and magnesium. The distribution of areas with different salt concentrations in the ground water in separate areas of the Golodnaya Steppe is shown in Table 3.

The general type of ground water cycle for most of the Golodnaya Steppe is climatic, characterized by the highest levels in spring (March and April) and the lowest in fall (September and October).

In some parts of the steppe, factors introduced by irrigation interfere with the maximum and minimum depression of the ground water level at one place or another.

Soils

The soils of the Golodnaya Steppe were formed basically from decomposition products of the surrounding rocks and alluvium from the Syr-Dar'ya river. The basic soil types are sierozems and meadow soils.

The sierozems developed chiefly on fine- and coarse-textured loess-like clay loams. The vegetation of the undrained portion is represented by ephemerals with a vegetative cycle of one or two months which is closely related to the moisture conditions in the upper horizons of the soil. The scanty remains of the dead plants are quickly and almost wholly mineralized. For this reason the sierozems of the Golodnaya Steppe are low in organic matter. They are distinguished by their high carbonate content and by the presence of water-soluble salts in different horizons, depending on the depth of the water table. The adsorption capacity of sierozems is not great, from 11.0 to 13.5 milliequivalents in the clays and up to 7 milliequivalents in the sandy loams. A distinctive feature of sierozems is their content of microaggregates. The size of the aggregates varies between 0.1 and 0.01 mm. This structure provides the soil with good capillarity, reaching four meters and higher.

Meadow soils were formed with constant or periodic capillary supply of the upper soil horizons from a shallow water table. Depending on the rate of the capillary process they are divided into alluvial-meadow, meadow, sierozem-meadow, and meadow-bog soils.

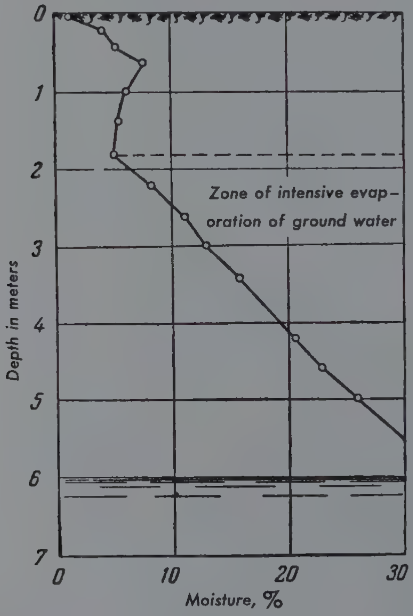

FIG. 2.—The dynamics of soil moisture along the profile on virgin lands of the Golodnaya Steppe in percent of the weight of the soil.

Alluvial-meadow soils are characterized by alternation of the particle sizes along the profile as a result of periodic flooding. After the constant flooding has stopped, the soils become covered with grass or woody (dense) vegetation. In the flooded portions of the soil some leaching has taken place and most often there is no salinization. Salinization increases, however, with increasing distance from the river.

Meadow soils are associated with low-lying parts of the relief and with regions in which the water table is close to the surface. The humus layer may reach 50 to 60 cm. The gypsum layer lies at a depth of 50 to 150 cm. The soils have a high carbonate content. Adsorption capacity is 8 to 13 milliequivalents. Ca^{++} predominates among the adsorbed cations.

Sierozem-meadow soils are subjected to the periodic action of capillary flow from the ground water. They represent an intermediate link between sierozems and meadow soils.

Meadow-bog soils develop under conditions of constant and abundant capillary moistening, but with periodic drying of the upper horizons.

Some Hydrophysical and Chemical Properties of Soils

As already noted, in the hydrogeological zone of dispersion (from which almost all the Golodnaya Steppe is derived) the inflowing surface and subsurface water is lost chiefly by evapotranspiration. To be convinced of this, one has only to turn to a graph of the dynamics of the moisture change along the soil profile on a virgin plot (Fig. 2). The data from the graph show that the amount of the capillary rise at the moment when the soil sample was taken for analysis was 4 m. Laboratory determination of the height of the capillary rise gives a considerably smaller figure. Observation shows that evaporation of the ground water from the capillary zone takes place from depths of 1.8 to 5.5 m. (Fig. 2). If this evaporation did not exist, then the moisture curve in the graph would have to approach a vertical line arising from the water table, but this is not the case.

In the example under consideration the soils are relatively uniform, so that an increase in moisture at a depth of 60 cm. from the surface can evidently be explained by a zone of condensation of water vapor coming both from the lower horizons of the soil and from the atmosphere. In other investigations it was shown that when the water table is 508 cm. below the surface, the capillary moisture layer is 210 cm. thick, while the layer with a moisture content close to the maximum molecular moisture capacity is about 250 cm. thick. Above this layer the moisture amounted to less than 10% of the weight of the soil. When the water table was 773 cm. down, the layer of capillary saturation was 230 cm. thick, and the layer with a moisture content equal to the maximum molecular moisture capacity was 200 cm. thick. When the water table was 1570 cm. down, the height of the capillary saturation rose 260 cm. above it, while the layer with a moisture content equal to the maximum molecular moisture capacity was 250 cm. thick. Above this was a layer with a moisture content of less than 10% of the weight of the soil attaining a thickness of up to 6 m. Only at 11.5 m. above the water table did the moisture content decrease to less than 10% of the weight of the soil. Thus, when the water table is relatively near the surface, the height of the zone of capillary saturation decreases, because of evaporation, to 190 to 200 cm., but it increases to 250 to 260 cm. when the water table is relatively deep. The thickness of the belt with moisture in films varies, depending on the depth of the water table, from 50 to 250 cm. Obviously, the upper limit of the capillary-molecular rise in soils of the Golodnaya Steppe would be about 4.0 to 5.0 m., since in the fine-textured soils of the Fergana valley this figure does not exceed 1.5 m. The height and speed of the capillary rise will be characteristic of the energy with which salinization is restored and consequently also of the necessary depth at which the drains should be placed.

Direct proof of the continuous evaporation from the capillary zone is furnished by the salinization of the water along the profile (Table 4) and by the deposition of salts in the soil.

The virgin sierozems of the Golodnaya Steppe do not at present have salinized upper layers (Table 5), but unless appropriate measures for improvement are taken, the ground water will rise and the soils can become salinized.

TABLE 4

Salinization of ground water along the profile in unirrigated lands of the Golodnaya Steppe.

Drilling number	Depth from which sample taken, meters	Salinization, grams per liter						
		Solid residue	Cl^-	$SO_4^{=}$	HCO_3^-	Ca^{++}	Mg^{++}	$K^+ + Na^+$
1195	2	8.496	0.487	4.722	0.281	0.527	0.706	0.744
	6	6.976	0.757	3.490	0.476	0.507	0.788	0.272
	10	4.240	0.157	2.733	0.119	0.562	0.202	0.429
	15	5.208	0.174	3.469	0.095	0.602	0.296	0.560
	20	5.096	0.122	3.026	0.095	0.572	0.258	0.417
1203	2	26.848	4.454	11.472	0.610	0.268	0.640	7.094
	6	11.080	0.800	6.672	0.244	0.474	0.517	1.818
	15	13.272	3.689	4.944	0.244	0.690	0.592	2.942
	20	12.040	3.410	4.464	0.244	0.711	0.517	2.645

On virgin lands the amount of salts in the ground increases with an increase in depth as a result of evaporation of the ground water from the capillary zone. But, if we start with a depth of 7.4 m. and the amount of salts fixed above the water table, and if we grant that this quantity of salts, because of a rise in their level, were to be concentrated in the top meter of ground, then the solid residue would be 704 metric tons per hectare of which the chlorine would amount to 7 metric tons per hectare. With such a salt content in the root zone no argiculture at all would be possible unless appropriate soil improvement measures were to be taken, since the permissible chlorine content must not exceed 1.5 metric tons per hectare.

In individual natural depressions of the Golodnaya Steppe (Sardobinsk, Shuruzyak, Dzhetysai, and others) the salt content is even greater (Table 6).

In some parts of the Golodnaya Steppe the salt content in the soil above the water table at dif-

TABLE 5

Salt content of virgin sierozems of the Golodnaya Steppe as percent of weight.

Horizons in cm.	Solid residue	Chlorine
0–100	0.096	0.004
101–300	0.368	0.002
301–540	0.651	0.014
541–660	0.600	0.037
661–740	0.632	0.036

TABLE 6

Content of salts along the profile of some depressions of the Golodnaya Steppe, as percent of weight.

Place where sample taken	Depth in meters	Solid residue	HCO_3^-	Cl^-	$SO_4^=$
Sardobinsk depression	1	1.164	0.014	0.021	0.763
	3	0.738	0.014	0.015	0.430
	5	0.628	0.017	0.012	0.257
	10	1.998	0.018	0.525	0.682
	12	2.292	0.010	0.512	0.891
	15	1.540	0.018	0.559	0.330
	20	1.036	0.023	0.414	0.197
Shuruzyak depression	1	2.690	0.048	0.086	1.645
	3	0.690	0.061	0.054	0.322
	5	1.134	0.054	0.053	0.656
	10	0.206	0.030	0.031	0.080
	11	0.240	0.037	0.045	0.087
	15	0.294	0.024	0.045	0.127
	18	0.254	0.029	0.021	0.127

TABLE 7

Salt content in the soil above the water table in metric tons per hectare.

Place from which sample taken	Depth of water table, meters	Total salts	Salts most harmful for plants			
			NaCl	$MgCl_2$	Na_2SO_4	$MgCO_3$
Soils which are practically unsalinized in the surface horizons						
Northwest part of the plateau	9.7	1240	10.6	75.5	2.8	236.0
Northeast part of the plateau	15.0	2190	276.0	126.2	86.4	579.0
Central part of the plateau	19.0	3460	405.0	306.0	231.1	676.0
Southwest part of the plateau	10.9	2200	230.0	187.5	92.7	561.0
Weakly salinized reclaimed lands						
Mirzachul' area	4.1	1790	71.9	87.0	72.0	314.0
Areas adjoining the flood plain of the Syr-Dar'ya river	2.5	3760	160.0	39.2	35.4	135.0
Solonchaks						
Around Dzhetysai	7.6	2420	245.5	206.0	481.0	373.0
Shuruzyak flood plain	1.7	5770	167.0	43.2	85.5	142.3
Dzhetysai depression	4.0	1070	62.5	123.0	3.5	153.0

ferent depths reaches colossal proportions—from 1000 to 6000 metric tons per hectare (Table 7). This quantity of salt is continuously increasing due to the arrival of new amounts from both the surface and ground water. For this reason, if the required measures for soil improvement are not taken promptly, there will be an unavoidable rise of the ground water with salinization of the root zone of the soil, as has already occurred more than once in individual areas at other locations in the Golodnaya Steppe.

Rise in Water Table with Irrigation

Before irrigation of the Golodnaya Steppe, a water table depth of less than 5 m. was observed only on the flood plain of the Syr-Dar'ya river, on certain portions of the Shuruzyak depression, and in depressions of the plain. In the remaining portions now under irrigation the ground water is at a depth of 10 m. or more from the surface and its salt concentration varies from 1 to 20 grams per liter. The salt concentration is higher in depressions and lower on watersheds.

The established levels of the ground water were disturbed in the first years of irrigation and they rose in the Shuruzyak depression to depths of 0 to 1 m., on the watershed between the Shuruzyak and Sardobinsk depressions to 2 to 3 m., and in the area of the Pakhta-Aral state farm to 3 to 4 m. With a further increase of the proportion of land in use which has been accompanied in recent years by the sowing of rice, the ground water has risen even higher and on most of that part of the Golodnaya Steppe lying in Uzbekistan it is at a depth of 1 to 2 m.; on the Pakhta-Aral state farm it is at 1.5 to 2.5 m.

Salinization of the ground water under old-irrigated fields varies from 2 to 8 grams per liter; under fallow and stubble it reaches 30 to 40 grams per liter and higher of solid residue. If there is further extension of the irrigated acreage on the Golodnaya Steppe without taking prompt and energetic measures, the existing water balance at any depth of the water table will inevitably be disturbed; for as the supply of irrigating water is increased, it is followed by an increase in the supply of subsurface water as a result of seepage from the canals and irrigated fields. Investigations which we carried out showed that the seepage of water from canals with earth channels amounted to an average of 30 to 40%

of the main water intake. The ground water is supplemented to a considerably smaller degree (not more than 10% of the net irrigation allotment) by seepage from irrigated fields.

The water balance will be disturbed again because that part of the subsurface water which is now being expended on evapotranspiration will decrease, since on irrigated fields for most of the time it will be irrigation water, not ground water, which is evaporated and transpired. For example, on the Pakhta-Aral state farm in the first year, the ground water rose from a depth of 9.6 to 5.2 m. The water table subsequently rose somewhat more slowly because of intensification of evapotranspiration, but it has not stopped rising and it will continue to rise until there is a new relative equilibrium between the incoming and outgoing elements of the water balance. When the water table rises the salts deposited in the capillary zone of the soil begin to dissolve and to be carried toward the surface of the soil salinizing the root zone. For this reason the rising ground water must be kept at such a depth that it not only will not interfere with intensive agriculture, but that it will make it possible. On the Golodnaya Steppe this depth averages close to 2 m. As research has shown, at such levels of ground water and with its wetting under the influence of irrigation, meadows will develop which make it possible to obtain the greatest yield of cotton, grasses, and other agricultural crops with the least expenditure of water on irrigation and of labor on subsequent tillage. A clear example of this is provided by the Pakhta-Aral state farm which, in 1956, with only two or three irrigation floodings during the growing period, produced an average cotton yield of 35 centners per hectare from an area of 5,250 hectares.

The rate of rise of the water table with irrigation will depend wholly on the economic and organizational conditions on the newly reclaimed lands. If water utilization, planning, and tillage are carried out rationally and the rice sowings are transferred to the bottom level of the flood plain, then the ground water will rise slowly.

Ground water rises with sprinkling, but more slowly. Experiments carried out on the Pakhta-Aral state farm on an area of more than 100 ha. showed that when irrigation consisted of sprinkling 300 cubic meters per hectare, the water table which lay at about 2 m. below the surface rose by 30 cm. and more. This rise took place not because the irrigation water mixed with the ground water, but because evapotranspiration of the ground water stopped while the continuous inflow not only went on as before but even increased somewhat as a result of seepage from the irrigation ditches. It is possible to get rid of seepage of water from the ditches by using waterproof linings (canal surfacing). But these are too expensive for construction and further exploitation. To stop the seepage of water from the ditches it is necessary to cement the entire permanent irrigation network, both large and small channels, down to and including irrigation ditches. According to my calculations this action, even for treatment on a large scale, costs about 9,000 to 10,000 rubles per hectare.

Seepage water from a relatively drainless oasis is not lost without a trace. Modern engineering makes it possible to raise this water to the surface and use it again for irrigation. This considerably reduces the water intake from rivers, and consequently the supply of ground water decreases. Seepage water from the ditches will add to the ground water and thus help to improve the condition of the area.

At the very beginning of reclamation, thorough consideration must be given to the conditions for irrigating all the crops to be sown and to the organizational planning for the water utilization; canals must be completely closed off except in the growing season, and water supply must be at the expense of the subsurface water. Special attention should be devoted to the composition of the crops to be sown.

The sowing of rice on the Golodnaya Steppe should be categorically forbidden, except on the flood plain of the Syr-Dar'ya river. In recent years the sowing of rice has caused a considerable decline in the soil improvement status of the Steppe. On those plots where rice has been set out the soil has indisputably been eluviated; while plots adjoining rice sowings have become salinized and in places even waterlogged. The smaller the area of a rice plot, the less damage it causes. With a range of the depression curve extending 300 m. from a rice plot, one hectare sown in rice can remove from cultivation up to 30 ha. of adjoining land. Rice sowings, being located near main and lateral drains, cause landslides in their banks; the watershed from the rice fields overflows the drainage network, as a result of which the network stops collecting and leading off the ground water and, instead, begins to supply it. The water from the rice fields forces the ground water into the beds of the drainage ditches, which leads to intensified filling in and accumulation of mud. Furthermore, this leads to extra material expenditures for cleaning all this out.

In 1956, having taken note of the Uzbekistan "experience in rice sowing," Kazakhstan sowed rice on 1869 ha. of its area of the Golodnaya Steppe, which led to an abrupt deterioration of its soil improvement status regardless of the new network of main and lateral drains which had been constructed during this period.

The rice sowings led to a sharp increase in the areas where the water table was less than 2 m. from the surface. And under Golodnaya Steppe conditions a water table 2 m. from the surface is associated with the danger of salinization.

At the present time Kazakhstan is refusing to continue the rice sowings on its area of the Golodnaya Steppe except on the flood plain of the Syr-Dar'ya river.

The soil improvement status of the old-irrigated areas of the Golodnaya Steppe is becoming rapidly worse with the introduction of vast new areas into the agricultural cycle. For this reason a system of soil improvement measures should be contemplated not only for lands to be newly irrigated, but also for those long under irrigation. The soil improvement system should include a complex of agrotechnical, organizational, and engineering measures, and if the basis of the engineering improvements is to be the construction of drainage systems, then their type and method of construction should be given special attention in the assembling of construction projects for the reclamation of the Golodnaya Steppe. The use of covered drains in loess and quicksand, in the same way in which this is being tried at the Soil Improvement Station at Zolotaya Orda (light construction), is not expedient since massive disturbances would be inevitable in this work, and its restoration would be an exceedingly complex and expensive affair. If covered drainage is to be used, then its construction should be solid and complete. Such drainage should be prepared from asbestos-cement or burned-clay pipe three to four m. long. The individual tubes should be connected by tightly sealed couplings. The water should enter the tubes through diagonal slits cut from below. The slits are at a distance of 8 to 10 cm. apart. The slits should be not more than 2 mm. wide and 5 to 7 cm. long. The tubes should be placed on a stable gravel foundation. The thickness of the underlying gravel layer in quicksand should be not less than 40 to 50 cm. Only under these conditions will it be possible to expect some kind of satisfactory work from covered drainage on the Golodnaya Steppe. Covered drainage should be combined with open drainage; the laterals should be open, the drains closed. The horizontal drains and laterals for the Golodnaya Steppe should be located not less than 2.5 to 3.0 m. deep. The distance between drains may vary from 100 to 400 or 500 m. depending on the soil, the coefficient of land utilization, the period of irrigation, and the location of the plot. On the basis of water balance calculations, the unit spacing of drains should be about 60 meters per hectare for the Sardobinsk and Dzhetysai depressions, 40 for the Shuruzyak depression, 25 to 35 for the general plateau of the Golodnaya Steppe, and 20 to 30 for the flood plain area.

TABLE 8

Percentage of areas having the water table at different levels on the Kazakhstan portion of the Golodnaya Steppe in 1953 and 1956.

Year	Percentage of area having ground water at different depths						Remarks
	0–1 m.	1.0–1.5 m.	1.5–2.0 m.	2.0–3.0 m.	>3 m.	Total	
1953	—	1.8	5.4	32.2	60.6	100	No rice sown
1956	2.3	3.3	10.0	28.0	56.4	100	With rice sowings

The most radical method of drainage for the irrigated lands of the Golodnaya Steppe will be vertical drainage. It should be given primary consideration here. It may be used on a broad scale under all natural and economic conditions. The study of vertical drainage on the Golodnaya Steppe made by G. D. Antonova showed that it gives excellent results. The ground water pumped from vertical drainage wells may be used successfully for irrigating agricultural crops. Of the agrotechnical measures, we recommend careful planning of all newly reclaimed lands; current planning should be carried out annually for all lands. No irrigation of newly reclaimed lands should be allowed without previous deep plowing, harrowing, and other cultivation of the soil in order to decrease the seepage of water from irrigated fields. It is first necessary to establish rigorous standards of water requirements on the fields and to introduce planned utilization of water into all units, including the crop-growing brigade. To regulate the water relations during the growing period, crop rotations with a maximum use of alfalfa can be recommended. A desirable ratio is 3:4 and 3:5. Tree plantings should be carried out along all permanent canals, main drains, and the boundaries of collective and state farms and brigade plots. Special plots of land should be set aside for woods and groves.

To reduce the intake of water from the river, much of the year's drainage water should be used for irrigation and leaching either undiluted or mixed with surface water.

During times other than the growing period, the admission of water to all the main canals of the Golodnaya Steppe must be completely stopped; the water supply should come chiefly from subsurface water.

Carrying out all the necessary measures for improvement will convert the old "hungry steppe" into a steppe with an abundance of agricultural products.

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PODZOLIZATION AND ILLIMERIZATION (CLAY MIGRATION)

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Since the time of V. V. Dokuchayev's (7) introduction into soil science of the concepts of podzolic soils as a genetic type, two points of view have arisen concerning the essence of the podzolization process. Some authors consider that in podzolization there is removal of the clay particles from the upper horizons of the soil without destruction of these particles (V. N. Amalitskii, 1; E. Wollny, 29; A. N. Sokolovskii, 13, 14; K. D. Glinka, 5). Other authors consider podzolization to be the destruction of clay particles in the upper part of the soil profile and removal of the products of this destruction (A. K. Georgievskii, 4; K. K. Gedroits, 3; A. A. Rode, 12; and others). The Rumanian soil scientist Cernescu (19, 20) combined these points of view, suggesting that podzolized soils be divided into two groups, one of which is characterized by the removal of clay without destruction, while in the other the clay particles are destroyed. Cernescu's first group is associated with less moist conditions and less acid humus, the second with more moist conditions and more acid humus. With acidification of the reaction (associated with a change in vegetation, leaching of the profile, and so forth) in the soils of the first group, the migration of the clay along the profile without destruction may be replaced by destruction of the clay-podzolization.

Similar conclusions were reached by Duchaufour (22, 23), Dudal (24) and other authors who studied the forest soils of western Europe. At the suggestion of Duchaufour, the process of removal of clay particles without destruction was designated *"lessivage,"* while the term "podzolization" was reserved for the transfer process associated with the destruction of the clay particles. *"Lessivage,"* in Duchaufour's opinion, prepared the conditions for the development of podzolization. Duchaufour emphasized that in the first process, the composition of the clay along the profile was uniform; in the second, it varied.

A summary of the determinations of the complete composition of the clay fraction of various podzolized soils, carried out by a number of investigators (A. A. Rode, 11; Brown and Byers, 17; Brown and Thorp, 18; N. A. Nogina, 10; L. E. Novorossova, 9; V. M. Fridland, 15; O. A. Vadkovskaya, 2; V. Zaboyeva, 8; and others), showed that according to this characteristic all podzolized soils are actually divided into two groups. In one group the complete composition of the clay in all the horizons remained constant; in the other it changed, repeating the course of the changes of the total composition of all soil, that is, an accumulation of SiO_2 was observed in the clay of the podzolized horizons, while an accumulation of R_2O_3 was observed in the clay of the illuvial horizons.

Micromorphological investigation of the soil which has been so widely developed in the last few years (McCaleb, 27; Frei and Cline, 25; Cline, 21; Kubiena, 26; and others) has shown that there are two groups among the podzolized soils, the first with oriented clay and the second without it. Oriented clay is defined by these authors as clay particles oriented along the direction of their vertical course, fissures, pores, and so forth, in the soil. The regularity with which the oriented clays are distributed in the soil profiles studied is the basis for the author's assertion that migration of the clay particles in the profile is the cause of the formation of the oriented clays. The authors of the papers cited, as well as Pallmann et al. (28), came to the conclusion that removal of the clay takes place in weakly acid soils, but when the acidity is intensified destruction of the clay particles begins.

Thus, recent research has confirmed Cernescu's conclusion regarding the existence of two different processes of differentiation of the silicate profile of the soil.

We have studied a number of soils whose structures display clear signs of podzolization. The data obtained has made it possible to arrive at certain supplementary conclusions regarding the nature of podzolization. In the present article we will consider only four soil profiles:

No. 20. Humic-illuvial podzol. Described in the Carpathians in the Rumanian People's Republic at an altitude of about 1600 m. under trailing pine brushwood; parent material of coarse-texture clay loam of eluvium.

No. 62. Cinnamon-brown podzolized (the reddish, light-brown podzolized forest soil of Rumanian authors, the Mediterranean podzolized burozem of eastern European authors). Described near Bucharest in the Rumanian People's Republic under a mixed broad-leaved forest with scanty mixed-grass cover; parent material of silty clay loess.

No. 1. Deeply podzolized gleyed soil. Described near Khabarovsk on a weakly dissected terrace of the Ussuri river under a cutover forest, now regenerating, of oak, ash and alder with an undergrowth of willow, nut trees, honeysuckle and a thick ground cover of mixed grasses and grains; parent material of clay-silty clay.

No. 11. Light-brown podzolized forest soil (the *sol lessivé* of French authors, the *Parabraunerde* of German authors). Described in the Teutoberger forest (beech, with a scanty admixture of oak and spruce) near Jena in the German Democratic Republic; parent material of silty medium clay loam loess, underlain by limestone at a depth of 130 cm.

The particle size analyses of the profiles studied are shown in Table 1.

TABLE 1

Particle size analysis of soils.

(Analysis by V. F. Mochalov and N. A. Kamennyi)

Profile No.	Depth in cm.	Loss on HCl treatment	Content of fraction in % (particle size in mm.)							Loss or gain in mineral clay as % of parent material
			1.0–0.25	0.25–0.05	0.05–0.01	0.01–0.005	0.005–0.001	<0.001	<0.001 after H_2O_2 treatment	
20	0–4	1.5	31.5	20.8	18.2	6.4	13.1	8.5	1.9	−63
	8–13	0.2	36.3	33.5	12.6	5.5	9.3	2.6	2.4	−52
	20–26	4.5	37.1	27.2	11.0	2.3	9.4	8.6	6.3	+25
	38–44	6.4	33.5	28.1	12.7	2.3	9.3	7.7	7.3	+45
	65–70	1.6	14.1	34.2	27.3	7.1	10.5	5.3	5.1	0
62	0–10	3.3	0.4	4.3	48.1	3.4	15.4	25.1	23.1	−27
	15–25	2.4	0.2	4.6	44.4	6.3	15.6	26.5	26.1	−17
	35–45	2.6	0.2	1.5	43.7	9.3	13.5	29.3	29.3	−7
	52–62	2.7	0.2	1.7	40.3	9.0	13.6	32.4	32.4	+3
	75–85	3.0	0.2	1.7	40.4	7.8	13.1	33.9	33.9	+8
	105–115	2.7	0.1	1.6	42.7	8.3	12.2	32.4	32.4	+3
	125–135	2.9	0.1	1.8	42.0	8.0	12.4	32.8	32.8	+4
	150–160	2.8	0.1	2.3	41.5	8.7	12.6	31.9	31.9	+1
	170–180	3.0	0.1	2.3	43.0	9.0	11.1	31.5	31.5	0
	225–235	12.0	0.1	1.4	36.9	8.2	9.9	31.5	31.5	0
1	0–7	2.4	2.9	6.8	33.8	15.5	17.3	21.3	14.0	−55
	12–20	1.2	2.0	0.7	40.1	14.9	18.3	22.8	20.9	−44
	25–35	0.5	1.2	13.7	29.2	16.0	16.7	22.6	21.3	−32
	40–50	1.2	1.4	5.8	37.4	12.8	17.3	24.1	22.7	−28
	95–105	4.5	0.5	3.0	26.8	10.5	15.9	38.8	37.8	+20
	135–145	1.9	0.3	0.0	33.8	11.6	17.3	35.1	33.7	+7
	180–190	1.8	0.3	6.7	24.6	12.1	18.6	36.0	34.8	+11
	210–220	2.1	0.2	33.2	8.6	6.1	16.0	33.9	31.4	0
	240–250	2.0	0.1	0.0	29.8	9.9	17.1	41.1	40.6	
11	1–4	2.5	7.9	14.9	44.7	5.9	13.7	10.4	5.9	−70
	6–16	1.0	1.0	6.3	63.0	6.4	13.0	9.3	8.8	−56
	30–40	1.6	0.9	3.5	49.2	7.6	10.9	26.3	25.7	+28
	55–65	1.8	0.8	6.4	46.3	8.1	11.1	25.5	25.3	+13
	85–95	2.1	1.1	10.9	44.5	7.0	11.6	22.5	22.3	+11
	120–130	10.0	0.7	8.7	42.2	7.6	10.2	20.6	20.1	0

In all the profiles studied there was clear evidence of reductions of the clay fractions of some horizons and increases of it in others, and in all cases the reductions were more abrupt and concentrated in a thinner layer than were the increases. The intensities of reduction and increase of profiles 20, 1 and 11 are quite similar (profile 1 is distinguished only by a greater thickness of the area of reduction), while profile 62 displays a significantly lower intensity of reduction and increase. This is distinctly associated with the high degree of saturation of the absorbing complex and the considerably less acid reaction of profile 62 as compared with other profiles (Table 2). Profile 20 is distinguished by its exceptionally high intensity of unsaturation and its very acid reaction. The humic-illuvial horizon (20 to 26 cm.) has an exceptionally high degree of unsaturation and acidity. Profiles 1 and 11 are very close together in their reactions, their degree of unsaturation and humus content, and occupy a position intermediate between those of the other two sections considered previously. The most substantial differences between profiles 1 and 11 are in the cation exchange capacity and in the content of exchangeable magnesium, which is higher in profile 1, and in the presence of gleying in profile 1, as we have seen above. Profile 20 differs sharply in the distribution of humus along the profile (existence of a humic-illuvial horizon) and in the differentiation of various forms of organic substances (change in the C:N ratio). Characteristic for profile 62 is the deep humus content and changes in the C:N ratio along the profile, the latter a characteristic of steppe soils. Profiles 1 and 11 proved to be similar occupying an intermediate position here as in other characteristics. They display an abrupt decrease in the humus content with depth and a somewhat decreased C:N ratio in the topmost horizon showing a wealth of nitrogen deposited there.

Profile 20 differs from the others when complete chemical composition of the soils is con-

TABLE 2

Some chemical properties of soils.

(Analyses by N. A. Andreyev, L. A. Bulayev, V. F. Mochalov and G. G. Rusakov)

Profile No.	Depth in cm.	Hygroscopic water, %	pH		Humus, %	Nitrogen, %	C:N	CO$_2$	Adsorbed cations in me./100 g. of soil				Saturation, %	Acidity (after Sokolov) in me. per 100 g. of soil		Cation exchg. cap'y me./100 g. of soil
			water	salts					Ca^{++}	Mg^{++}	H^{+a}	Total		H	Al	
20	0–4	2.80	4.01	2.91	21.58	0.75	16.7	Not det'd	6.25	3.00	12.5	21.25	41.2	0.45	2.94	not determined
	8–13	0.61	4.15	3.12	1.56	0.04	22.5	“ “	2.00	0.30	3.4	5.7	40.4	0.05	1.82	“ “
	20–26	3.84	4.34	2.80	10.88	0.24	26.2	“ “	3.15	0.50	18.2	21.85	16.8	0.05	5.93	“ “
	38–44	2.81	5.29	4.09	5.58	0.11	29.3	“ “	2.60	0.25	5.8	9.65	39.9	0.02	1.42	“ “
	65–70	1.18	5.73	4.37	0.85	0.04	12.3	“ “	3.60	0.59	0.9	5.09	82.3	0.02	1.29	“ “
62	0–10	3.21	7.22	6.35	9.53	0.46	12.0	“ “	33.95	6.00	0.2	40.15	99.5	0.08	none	“ “
	15–25	2.23	6.66	5.57	3.13	0.18	10.0	“ “	18.45	2.61	0.3	21.36	98.6	not determined		“ “
	35–45	2.27	5.97	5.33	1.43	0.09	9.2	“ “	17.15	3.00	0.1	20.25	99.5	0.05	0.03	“ “
	52–62	2.63	5.71	5.05	1.11	0.07	9.2	“ “	18.23	3.50	0.2	21.93	99.1	not determined		“ “
	75–85	2.85	5.83	4.44	0.96	0.07	7.9	“ “	19.70	4.25	0.3	24.25	98.8	0.05	0.03	“ “
	105–115	2.97	5.74	4.82	Not det'd		—	“ “	21.30	2.07	0.3	23.67	98.7	0.02	0.03	“ “
	125–135	2.98	5.73	5.25	“	“	—	“ “	19.60	4.00	0.2	23.80	99.2	not determined		“ “
	150–160	2.99	5.83	5.30	“	“	—	“ “	22.70	3.82	0.1	26.62	99.6	“	“	“ “
	170–180	3.04	5.76	5.18	“	“	—	0.20	23.40	3.82	0.1	27.22	99.6	0.02	0.03	24.06
	225–235	2.74	7.78	7.00	“	“	—	3.90	Not det'd		none	—	100.0	not determined		23.39
1	0–7	3.85	5.96	4.58	7.14	0.40	10.3	Not det'd	24.21	4.24	1.2	29.65	96.0	0.14	0.05	not determined
	12–20	2.33	4.99	3.52	1.68	0.10	9.7	“ “	4.56	2.97	3.7	11.23	67.1	0.05	3.36	“ “
	25–35	2.12	4.92	3.45	0.95	0.06	9.1	“ “	3.71	2.97	5.2	11.88	56.3	0.05	4.04	“ “
	40–50	2.06	4.92	3.38	0.58	0.04	8.4	“ “	4.40	3.26	4.6	12.26	62.5	0.05	4.21	“ “
	95–105	2.75	4.94	3.73	0.61	0.03	11.7	“ “	12.28	9.89	1.9	22.17	91.4	0.07	1.49	“ “
	135–145	2.83	5.53	4.49	Not det'd		—	“ “	12.92	9.66	0.6	23.18	97.4	0.02	0.12	“ “
	180–190	3.13	5.61	4.78	“	“	—	“ “	14.16	10.89	0.2	15.25	98.7	0.02	0.03	“ “
	210–220	2.67	5.98	4.97	“	“	—	“ “	13.29	10.06	0.1	23.45	99.6	0.05	0.03	“ “
	240–250	3.49	5.98	4.96	“	“	—	“ “	15.22	11.89	0.1	27.21	99.6	0.05	0.03	“ “
11	1–4	3.60	5.06	3.98	7.39	0.58	7.4	“ “	18.66	1.86	1.3	21.82	94.0	0.04	0.47	“ “
	6–16	0.92	4.29	3.21	0.79	0.02	22.5	“ “	2.27	1.36	2.4	6.03	60.2	0.08	2.54	“ “
	30–40	2.54	3.98	3.19	0.45	0.02	12.8	“ “	6.00	0.92	5.5	12.42	55.8	0.08	5.76	“ “
	55–65	2.65	4.38	3.07	0.26	0.02	7.5	none	9.23	2.31	1.2	12.74	90.6	0.06	1.13	“ “
	85–95	2.53	5.51	3.89	Not det'd		—	“	12.81	1.84	1.8	16.45	89.1	0.04	0.12	“ “
	120–130	2.21	7.88	6.62	“	“	—	3.32	Not determined			—	—	0.04	none	“ “

[a] Displaced by barium chloride.

sidered (Table 3). Three processes can be distinctly seen: 1) intensive general removal of elements from the soil profile leading to the residual accumulation of silica and, in part, of titanium; 2) the biological accumulation of a number of elements, not only in the upper horizon of the usual organic accumulation, but, for some elements (phosphorus and sulfur) throughout the entire profile; 3) the accumulation of iron in the horizon in which clay has become concentrated (in the absence of accumulation of aluminum).

In profiles 1, 11 and 62, as opposed to profile 20, in horizons with an increased clay content there is noted not only an increased iron content but an even more clearly pronounced increase in the aluminum content. The greater accumulation of aluminum is shown by molecular ratios. In these profiles the general removal of elements from the profile is at a considerably lower intensity than in profile 20. As a result, the biological accumulation is no less active than in profile 20 and does not cause such an abrupt difference between the horizon accumulating organic matter and those lying below it.

The data regarding the complete composition of the clay fraction (Table 4) enable us to make some interesting conclusions. According to these data, the sections being considered are clearly divided into two groups. The first group consists of profile 20 in which the composition of the clay fraction changes abruptly along the profile repeating the same changes observed in the com-

TABLE 3

Complete composition of the soils.

(Analyses by N. A. Andreyev, K. Ya. Dorokhov and Z. N. Karayev)

Profile No.	Depth in cm.	As % of dry material		As percent of calcined, carbonate-free material													$\frac{SiO_2}{R_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{CaO + MgO}$	$\frac{Fe_2O_3}{Al_2O_3}$
		Hygroscopic water, %	Capillary moisture, %	SiO_2	R_2O_3	Fe_2O_3	Al_2O_3	TiO_2	P_2O_5	CaO	MgO	MnO	Na_2O	K_2O	SO_3	Total %					
20	0–4	3.34	25.68	84.85	12.12	2.28	8.97	0.63	0.26	0.30	0.90	traces	0.40	0.53	0.67	99.79	13.861	16.06	101.00	50.50	0.14
	8–13	0.56	2.05	88.33	8.93	1.30	6.97	0.47	0.19	0.07	0.66	"	0.53	0.81	0.44	99.77	11.359	21.65	184.00	81.77	0.12
	20–26	4.00	11.55	75.61	19.64	6.89	12.23	0.33	0.19	0.08	1.39	"	1.20	1.63	0.63	100.18	7.772	10.58	29.30	30.00	0.36
	38–44	2.88	7.26	74.24	20.19	4.65	15.06	0.37	0.12	0.08	1.64	0.08	1.39	1.57	0.54	99.74	7.018	8.41	42.63	17.90	1.20
	65–70	1.24	3.21	70.53	22.99	5.98	16.18	0.72	0.11	0.52	2.41	0.03	1.39	2.39	0.23	100.49	5.991	7.38	31.68	17.03	0.23
62	0–10	3.32	13.73	72.08	20.37	5.99	13.39	0.75	0.24	1.30	1.55	0.16	1.37	2.30	0.41	99.54	6.914	8.70	32.46	19.69	0.27
	15–25	2.48	5.80	73.49	20.21	4.98	15.28*	not detd.		0.69	1.77	not determined				96.16	6.806	8.22	39.52	21.88	0.21
	35–45	2.44	4.26	72.32	22.06	5.36	16.70*	"	"	0.68	1.75	"		"		97.81	6.087	7.35	35.44	21.52	0.25
	75–85	2.70	4.47	67.55	25.88	8.19	16.52	1.07	0.17	0.71	2.02	0.07	1.17	2.43	0.15	100.05	5.216	6.82	22.08	17.59	0.31
	150–160	3.46	3.71	70.31	24.12	6.31	17.81*	not detd.		0.68	1.91	not determined				97.02	5.477	6.70	30.05	19.53	0.22
	225–235	2.70	8.07	68.78	24.02	6.90	15.89	1.10	0.13	2.56	1.93	0.15	0.96	1.74	traces	100.14	5.753	7.34	26.63	12.18	0.28
1	0–7	3.74	16.00	70.99	22.71	5.45	15.49	1.51	0.26	1.56	1.16	0.40	1.44	1.50	0.86	100.72	6.360	7.78	34.76	20.75	0.22
	12–20	2.28	4.83	71.80	22.66	5.90	14.89	1.14	0.04	0.90	1.05	0.11	2.17	2.21	0.37	100.58	6.511	8.20	32.35	28.50	0.25
	25–35	2.16	4.08	72.30	21.42	4.97	16.45	not detd.		0.97	1.07	not determined				95.76	6.276	7.48	38.87	27.38	0.19
	40–50	2.14	3.66	71.52	22.18	5.12	17.06*	"	"	0.89	1.09	"		"		95.68	5.989	7.14	37.25	27.72	0.19
	95–105	3.56	4.67	67.05	26.51	6.29	18.62	1.51	0.09	1.07	1.26	0.04	1.99	2.38	0.67	100.97	5.054	6.14	28.64	21.90	0.21
	135–145	3.24	4.28	67.81	24.59	5.86	18.79*	not detd.		1.21	1.27	not determined				94.88	5.113	6.14	30.54	20.93	0.20
	180–190	3.32	4.63	68.61	23.91	5.42	18.49*	"	"	1.32	1.44	"		"		95.28	5.321	6.32	33.65	19.07	0.19
	210–220	3.18	4.07	69.62	24.05	6.02	18.03*	"	"	1.21	1.13	"		"		96.01	5.395	6.55	30.53	23.20	0.22
	240–250	3.50	4.63	66.86	27.16	7.61	18.49	0.89	0.17	1.06	0.91	0.04	1.87	2.25	0.44	100.59	4.865	6.15	23.21	26.52	0.27
11	1–4	4.44	21.63	79.29	13.47	2.94	9.76	0.76	traces	1.44	1.06	0.13	1.13	2.16	1.50	100.17	11.48	13.77	69.58	24.94	0.20
	6–16	1.02	2.32	79.98	11.08	3.14	10.12	0.82	"	0.40	1.04	0.07	1.05	2.26	1.06	99.93	11.20	13.47	66.65	31.00	0.20
	30–40	3.20	3.04	74.10	19.60	5.43	13.29	0.88	"	0.54	1.46	0.07	0.95	2.85	0.70	100.27	7.53	9.50	36.32	26.28	0.26
	55–65	3.02	2.91	72.10	20.28	5.54	13.95	0.73	0.06	0.68	1.57	0.03	0.92	2.81	1.56	99.95	7.02	8.83	34.31	23.55	0.26
	85–95	2.90	2.84	73.79	18.99	6.50	11.66	0.74	0.08	0.83	1.80	0.07	1.00	2.68	1.60	100.75	8.24	11.37	29.97	20.83	0.38
	120–130	2.62	5.93	73.58	18.61	5.69	11.86	0.88	0.18	0.71	1.86	0.08	1.05	2.38	1.96	100.23	8.07	10.57	34.05	20.43	0.31

* Total of Al_2O_3 , P_2O_5 and TiO_2 .

plete analysis of all soils, but in more abrupt form.

The second group consists of the remaining profiles in which the clay fraction remains uniform along the entire profile. There is a slight rise in the SiO_2/R_2O_3 ratio in the uppermost soil layer (the organic mat), the cause of which will be considered below. The absence of changes in the clay composition of the profile of these soils is confirmed by the study of their mineral composition. Since we are unable in this article to cite the data from all the profiles studied, we are using as examples data from only one of each profile. The clay fraction of profile 62 was analyzed in the Laboratory of Soil Mineralogy of the Dokuchayev Soil Institute under the direction of N. I. Gorbunov, using the method of differential thermal analysis (Fig. 1). This analysis revealed a high degree of similarity between the clay fractions from the 15 to 25 cm. and the 150 to 160 cm. horizons. The form of the thermogram provides a basis for assuming that beidellite, beidellitized hydromica and amorphous, weakly crystallized substances are predominant.

The differences noted in the composition of the clay fractions of the two groups of soils considered above make it possible to assume that the differentiation of particle size and total composition of the soils studied is connected with two different processes: 1) the actual podzolization, that is, destruction of the clay fraction and the differential removal of the products of this destruction (profile 20); and 2) the transfer of the clay fraction without destruction of the clay

TABLE 4

Total analysis of the clay fraction (particles <0.001 mm.).

(Analysis by K. Ya. Dorokhova)

Profile No.	Depth in cm.	As % of dry material		As % of calcined, carbonate-free material							$\frac{SiO_2}{R_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{CaO + MgO}$	$\frac{Fe_2O_3}{Al_2O_3}$
		Hygroscopic water, %	Capillary moisture, %	SiO_2	R_2O_3	Fe_2O_3	$Al_2O_3 + P_2O_5 + TiO_2$	CaO	MgO	Total					
20	0–4	7.36	52.27	61.23	33.41	7.93	25.48	0.26	2.86	97.76	3.40	4.08	20.42	13.26	0.20
	8–14	5.19	19.76	58.50	37.01	3.93	33.08	0.09	2.16	97.76	2.79	3.03	39.00	17.41	0.08
	20–26	11.34	42.75	40.45	56.18	29.17	27.01	0.12	2.60	99.35	1.51	2.54	3.70	10.06	0.69
	38–44	9.39	34.78	46.48	48.25	24.49	23.76	0.18	4.32	99.23	2.03	2.33	5.20	6.98	0.64
	65–70	5.52	12.46	48.83	43.43	12.94	30.55	0.08	4.40	96.80	1.66	2.71	4.26	7.33	0.64
62	0–10	8.26	20.84	53.79	40.61	12.23	28.38	0.15	3.10	97.65	2.53	3.23	11.80	11.21	0.27
	15–25	8.88	13.76	52.49	41.04	13.02	28.02	0.08	3.29	96.90	2.50	3.18	10.80	10.54	0.29
	35–40	9.20	12.86	52.80	40.76	13.23	27.53	0.08	3.23	96.87	2.49	3.26	10.60	10.73	0.31
	75–85	11.42	12.64	55.02	41.36	13.46	27.90	0.08	3.42	99.88	2.56	3.35	10.92	10.54	0.31
	150–160	12.54	9.53	54.42	39.78	12.90	26.88	0.08	3.17	97.45	2.64	3.45	11.20	11.34	0.31
	225–235	9.52	9.73	54.45	41.10	12.60	28.50	0.09	2.94	98.58	2.53	3.25	11.48	12.89	0.28
1	0–7	6.24	24.71	55.98	41.77	11.04	30.73	0.24	2.06	100.05	2.64	3.10	17.94	16.66	0.17
	12–20	4.64	14.54	53.73	44.18	13.13	31.05	0.27	1.64	99.82	2.32	2.94	10.91	19.46	0.27
	95–105	6.96	9.87	54.56	42.28	12.37	29.91	0.43	1.63	98.90	2.46	3.10	11.81	18.55	0.26
	240–250	6.32	9.15	54.06	42.10	13.11	28.99	0.51	1.95	98.63	2.47	3.17	11.12	15.53	0.29
11	1–4	6.62	31.95	61.76	32.92	10.73	22.19	0.92	2.97	98.57	4.30	4.72	15.35	11.43	0.31
	6–16	5.08	9.67	56.80	37.42	10.52	26.90	0.33	2.63	97.18	2.87	3.59	14.34	13.15	0.25
	30–40	16.28	12.20	54.86	38.66	12.97	25.69	0.30	3.08	96.90	2.75	3.64	11.28	11.15	0.32
	55–65	6.36	7.97	55.69	37.26	12.08	25.18	0.25	3.25	96.45	2.87	3.76	12.21	10.92	0.31
	85–95	7.16	7.93	54.75	38.12	12.76	25.36	0.29	3.62	96.78	2.77	3.66	11.40	9.60	0.32
	120–130	5.96	7.63	56.96	36.73	13.12	23.61	0.35	3.95	97.95	3.03	4.11	11.57	9.03	0.35

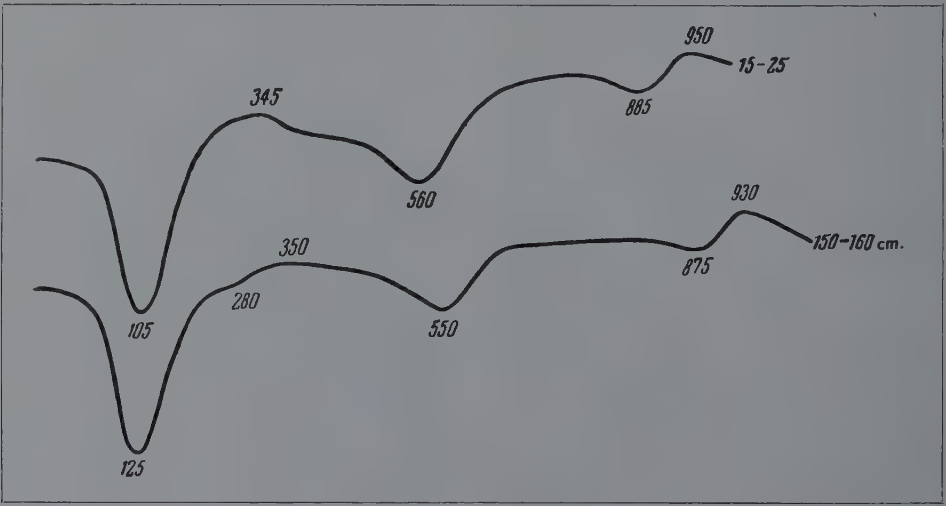

FIG. 1.—Thermograms of Profile 62

TABLE 5

Actual and calculated composition of the A_2 horizons.

	Profile 1 (12–20 cm.)			Profile 11 (6–16 cm.)			Profile 62 (15–25 cm.)		
	SiO_2	Al_2O_3	Fe_2O_3	SiO_2	Al_2O_3	Fe_2O_3	SiO_2	Al_2O_3	Fe_2O_3
Actual content (analyt. detd.)	71.80	14.89	5.90	79.98	10.12	3.14	73.49	15.23	4.98
Calculated content	73.90	15.89	3.65	79.63	9.27	4.25	72.56	15.30	5.89
Deviation as % of actual content	+2.9	+6.7	−38.1	−0.4	−8.4	+38.5	−1.1	+0.4	+18.2

TABLE 6

Actual and calculated composition of the B horizons.

	Profile 1 (95–105 cm.)			Profile 11 (30–40 cm.)			Profile 62 (75–85 cm.)		
	SiO_2	Al_2O_3	Fe_2O_3	SiO_2	Al_2O_3	Fe_2O_3	SiO_2	Al_2O_3	Fe_2O_3
Actual content (analyt. detd.)	67.05	20.22	6.29	74.10	13.29	5.43	67.55	16.52	8.19
Calculated content	66.16	19.95	6.86	70.50	13.18	6.38	67.19	16.59	7.21
Deviation as % of actual content	−1.3	−1.3	+9.0	−4.8	−0.8	+17.3	−0.1	+0.4	−11.9

minerals (profiles 1, 11 and 62). We prefer (16) to call this second process "illimerization" (Russian *obezylivaniye,* clay migration).[1]

To test the hypothesis of the transfer in the soil profile of the clay fraction without its differentiation, the following formula was developed (16):

$$S_x = S_o \pm (b - a)\,\frac{S_1}{100}$$

in which S_x is the percent of a given oxide in soil horizon x; S_o is the percent of the given oxide in the parent material; S_1 is the percent of the given oxide in the clay fraction; b is the percent of clay in the parent material; a is the percent of clay in soil horizon x.

The formula is used with a "plus" sign in calculating elements present in clay in quantities smaller than those in which they are present in the soil as a whole; it is used with a "minus" sign in calculating elements present in clay in quantities larger than in the soil as a whole.

This formula can be used only with soils having a uniform clay composition for all horizons, and is developed on the basis of the three following assumptions: 1) the parent material underlying the soil is uniform; 2) weathering, including clay formation in all horizons of the soil, takes place at a uniform rate; and 3) differentiation of particle size and total composition of the soil is caused only by the movement of unaltered clay in the profile.

A comparison of the values calculated according to this formula with the analytically determined values makes it possible to evaluate the correctness of the original concepts on the basis of which the formula was developed, including the concept of the differentiation of the profile because of the movement of unaltered clay which is our problem. The calculations were carried out for horizons A_2 and B of profiles 1, 11, and 62 which have uniform clay composition in all horizons. Determinations were made of the content of SiO_2, Al_2O_3, and Fe_2O_3, the total of which amounts to about 95% of the clay in all profiles. Tables 5 and 6 show the content of these elements in horizons A_2 and B of these three profiles, both as calculated according to the formula shown above and analytical determinations.

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[1] The term "lessivage" which Duchaufour suggested for the designation of this process is not exactly a fortunate one, since it designates leaching, or the removal of carbonates and other more easily soluble salts, and is used in this sense in soil science literature. Its use to designate a different process may lead to misunderstanding.

Deviation of the calculated from the actual content of silica was exceedingly small; for alumina it was somewhat larger but still not significant enough to speak of the incorrectness of the concept underlying the calculation. Furthermore, deviation of the calculated values from those determined analytically enables us to note that the differentiation of the particle size and total composition of the soil is caused not only by movement of unaltered clay in the profile, as is general for these soils, but by other processes, too.

The calculations shown emphasize the fact that the decrease in the amount of clay in the upper portion of the three profiles considered takes place not as a result of the destruction of the clay and the differential removal of the products of destruction, but as a result of the removal of the clay as a whole without destruction. We may consider this concept as proven since the calculations based on it for silica and alumina (which together constitute 85% to 90% of the clay fraction) gave fully satisfactory results. Furthermore, there is no doubt that the weathering which takes place in the soil, the biological cycle, and a number of other processes also exert a substantial effect on the differentiation of the profile. This effect is very clearly seen in the results of the calculation for iron, which differed materially in all three profiles from the values of the analytical determinations. Let us try to analyze these deviations.

In profile 1 the amount of iron analytically determined in the A_2 horizon was larger than the calculated amount while in the B horizon it was less. This was probably caused by the movement of the bivalent iron (which does not enter into the composition of clay) in this gleyed soil from the B horizon into the A_2 horizon with rising moisture currents during the dry period. In this way there is partial compensation for the removal of iron with the clay fraction. In the other two profiles the deviation in the A_2 horizon proved to be reversed; the actual quantity of iron was lower than calculated. In our opinion this was caused by weathering, which caused removal of iron additional to that related to its movement as a part of the clay fraction. In the illuvial horizons of these soils (Table 6) the deviations of the calculated amounts of iron from the actual amounts have different signs. In profile 11 the deviation keeps the same sign which it had in the A_2 horizon; while in profile 62 it takes on an opposite sign. Differences are related to the reaction of the illuvial horizons in question. In the more acid illuvial horizon of profile 11, the same process of weathering takes place as in horizon A_2 (however at a slower intensity, as shown by the smaller deviation); in the less acid illuvial horizon of profile 62, there is accumulation of the products of the weathering which is taking place in horizon A_2. These products supplement the iron introduced into horizon B with the clay fraction and reverse the sign of the deviation. The greater deviation of the calculated data from that determined analytically in profile 11 is related to the more acid reaction caused by a higher intensity of weathering than in profile 62, although the latter is actually richer in iron on an absolute basis. The fact that the deviation of the calculated from the determined values is considerably less for silica and alumina than for iron is explained by the fact that iron-containing primary minerals are more easily weathered than those not containing iron.

The calculations for Ca and Mg (not shown) gave even greater deviations than those for iron, which is quite natural considering that the migration of these elements in the soil is related to plant activity to a greater degree than to any other process.

Micromorphological investigations of these soils (microscopic study of thin cross-sections of the soil with undisturbed structure) provided too much data to be fully discussed in the present short paper, but it revealed the following: In profile 20, oriented clays are lacking. In profiles 62, 1, and 11 they are plainly detectable, being associated with pores, cracks, and other cavities in the soil and clearly formed as if by inflow; they accumulate most characteristically in the upper part of horizon B. The greatest concentration of oriented clay is in horizon B of profile 11 which, according to the particle size analysis, has the greatest accumulation of clay. Finally, the existence of distinctive iron films in the illuvial horizon of profile 62 definitely confirms the accumulation in it of iron freed as a result of weathering in the upper horizons, which is shown by chemical analysis and calculation.

Finally, let us consider the deviations in the composition of the clay which were noted in the topmost horizons of profiles 1, 11 and 62. We note that the clearest deviation is observed in the most acid profile, number 11, and the least pronounced is in the least acid profile, number 62.

The cause of this deviation is seen in the extremely high ratio (about 30) of SiO_2/R_2O_3 in the ash of beech, spruce and other leading forest types which exert a considerable influence on the composition of the clay in the uppermost soil horizon. The acid reaction of the soil, making possible more active removal of the sesquioxides as compared to silicates, intensifies even more the effect of plant deposits in increasing the ratio SiO_2/R_2O_3 in the uppermost soil layer. It also probably leads to the destruction of the clay in the same upper part of the soil profile—actual podzolization.

In conclusion, the removal from the upper part of the soil profile of the clay fraction and of the sesquioxides and the concentration of silicates in this part of the profile may be the result chiefly of two processes: the destruction of the clay with differential removal of the products of this destruction (podzolization); and the movement of undifferentiated clay without destruction of the clay minerals (illimerization or clay migration). Of the soil profiles considered above, profile 20 is podzolized and profiles 62, 1, and 11 are illimerized, but in the topmost layer of profiles 1 and 11 the beginning of podzolization is noted.

The most important indicators allowing us to distinguish between podzolization and illimerization (clay migration) are the data regarding the total composition of the clay fraction and the micromorphological examination of the soil. We do not yet have enough similar data at our disposal to speculate on the geography of these two processes. However, using our data (both that published in the present article and some which is unpublished) and sources in the literature, we put forward the following considerations:

1. Podzolization predominates in typical podzolic, gleyed-podzolic, humic-illuvial podzolic and sod-podzolic soils.
2. Illimerization (clay migration) predominates in soils related usually to the light-brown forest podzolized, brown podzolized (including the reddish, light-brown podzolized soils of Rumanian authors), in *Parabraunerde,* in the gray wooded soils, and in the yellow podzolic soils (zheltozem).
3. The combination of podzolization and illimerization is possible in a number of soils. Such soils would probably be related to some extent to the sod-podzolic soils, to some of the soils related to the light-brown forest podzolized (more acid) soils, and to some of the gray wooded soils and others.

Electron microscopy has made it possible to clarify the usual size of particles of clay minerals in parent material and soils. According to data assembled in the monograph of Grim (6), the size of clay particles as a rule is less than 1 micron; only in dickite and halloysite are the particles sometimes 4 to 8 microns along the long axis. These data confirm again the conclusion that movement is possible for clay particles in the soil since the dimensions of the soil pores and cavities, as a rule, are hundreds of times greater. It must also be kept in mind that the cavities, pores, and fissures on the surfaces of individual structural fragments are constantly changing, appearing, disappearing, and creating new possibilities for the movement of clay particles.

An important question is clarification of the position of the stabilizers which maintain the clay particles in a state of suspension. Such stabilizers may be organic substances, colloidal silica, or, in the opinion of Pallmann et al. (28), hydrogen adsorbed on the surface of the clay particles. While considering all three variants possible, we note that in illimerized soils the silica content of the horizons which have been enriched in clay is increased (see Table 4). This makes it possible to attribute to silicic acid the role of stabilizer of the argillaceous substances in their movement down the profile.

In conclusion it must be noted that the study of the distribution of illimerization (clay migration) and its mechanism is in the very beginning stages of solution. Both these questions are closely related and their solution is only possible with the combination of geographical and laboratory investigation. Of the laboratory methods, a very interesting one would be to make a model of the process with labelled clay substances and different eluviating solvents. Micromorphological research, study of the mineralogical composition and of the chemical and physicochemical properties of soils and their individual fractions, and careful study by horizons of the organic matter, could also be extremely useful for the solution of these questions. Special attention should be devoted to soil solutions and the composition of surface and ground water as well as to the role of surface gleying. In addition, in studying this process, careful consideration must also be given to the role of other conversion and migration processes in the soil: weathering and the formation of clay soils, the biological cycle, podzolization, and many others.

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SOIL CONDITIONS AND EXPERIENCE IN TEA CULTURE IN THE PRINCIPAL TEA-PRODUCING REGIONS OF THE EASTERN PART OF FUTSZYAN' PROVINCE, CHINESE PEOPLE'S REPUBLIC

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SPECIAL climatic features of the principal tea regions of the eastern part of Futszyan' province are characterized by high relative humidity, a mean annual air temperature of 15° to 17° C., and total annual precipitation of 1000 to 1200 mm. The mean relative humidity of the air is more than 80%; thick fogs are common. For this reason the tea plant, like all evergreen shrubs, grows well in these regions.

Natural conditions in the eastern part of Futszyan' province are favorable for the development of tea, but the tea plantations here are gradually becoming worse; their productivity is declining. Thus, in recent years the peasants have harvested from 1 mu[1] an average of only 20 to 25 tszin'[2] of dry uncured tea leaves of the local variety "Tsai-cha" (var. bo thea) and of 70 to 80 tszin' of dry uncured tea leaves of the variety "Tabai-cha."

The decrease in productivity of the tea plantations has occurred because the tea plants in these regions have for the most part become old and the system for fertilizing the tea plants is not rationally arranged. Furthermore, as a result of incorrect management there is much erosion of the soil, causing considerable damage to the plantations. It is obvious that in order to obtain new crops of tea and to establish new plantations and extend the old ones, a study of the soil is first needed.

In the six main tea regions[3] of the eastern part of Futszyan' province, krasnozem and zheltozem are predominant. Somewhat less widespread are the violet soils and podzolized krasnozems. It is known that when all these soils have a medium or slightly acid reaction, they are most favorable for the development of tea shrubs, but comparative research on the different soils of the main tea regions shows that they do not exert a uniform effect on the production of shoots. This is explained by the fact that the growth and development of the tea plant depends on the thickness of the soil. In the eastern part of Futszyan' province the thickness of the soil does not correspond to the requirements of the tea plants. Thus, for example, in thin krasnozem (that is, in which the combined A and B horizons amount to less than 100 cm.), horizon A goes down only to 15 cm., horizon B to 75 cm. The root system of tea develops only with difficulty in such thin soils. For this reason a 50-year-old tea plant grows poorly here: it reaches a height of 0.8 to 3 Chinese feet (average 1.8). In such tea plants the leaves have a yellow color and their production of shoots is low. From 1 mu the peasants gathered only 15 tszin' of dry raw tea leaves, that is, from each tea plant an average of less than 1 lyan (about 31.25 gm.). On the other hand, tea plants grow well in thick krasnozem (where the combined A and B horizons is more than 130 cm.). In thick krasnozems horizon A is up to 33 cm. thick, horizon B up to 147 cm. On a thick krasnozem a 50-year-old tea plant grows to an average of 1 Chinese foot in height, but at the base it may be 1.5 to 2.0 Chinese feet across.

Such shrubs form a strong, healthy frame, their production of shoots is intensified, and 300 tszin' of dry raw tea leaves may be gathered from every mu. This means that the productivity in tea leaves on thick krasnozem is twice as high as on thin krasnozem.

The soil reaction, nutritive substances, and water permeability all exert a definite influence on the growth and development of tea plants. Thus, for example, if the soil has a pH of more than 6.5 this means that its lime content is too high and the growth and development of the tea plant will be hindered. As shown by our research,

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[1] 1 mu = 0.06 hectare.

[2] 1 tszin' = 0.6 kilogram.

[3] The investigations were carried out on tea plantations in the villages of Kan-yan, Tsuy-tsya, Khan-gan, Mey-yan, and Tan-yan and on the experimental field at Fu-an.

TABLE 1

Particle-size and chemical composition of the soils of the main tea regions of the province.

Section No.	Soil	Depth of sample, cm.	Particle-size composition, %			Porosity %	Humus %	Total N, %	H^+ me.	Adsorbed cations me.	CH_3COONa			pH
			2–0.02 mm.	0.02–0.002 mm.	<0.002 mm.						NO_3N p.p.m.	P p.p.m.	K p.p.m.	
2	Violet	0–35	18.80	40.2	42.04	56.2	2.80	0.118	11.38	5.80	5.0	5.0	50	4.7
		35–120	15.30	43.7	41.00	51.96	0.98	0.065	6.08	3.75	<5.0	2.5	25	5.0
3	Zheltozem	0–50	34.80	25.20	40.00	61.65	2.33	0.093	10.24	6.20	12.0	<5.0	50	5.0
		50–150	27.80	35.20	37.00	54.79	1.58	0.080	6.27	3.90	<5.0	2.5	75	5.5
7	“	0–15	19.40	39.10	41.50	50.84	2.17	0.076	10.59	6.05	10.0	>2.5	50	5.0
		15–100	30.30	44.60	25.00	48.68	0.57	0.030	5.48	3.30	<5.0	<2.5	25	6.0
10	“	0–16	27.30	37.00	38.70	54.07	1.73	0.078	7.26	6.10	5.0	2.5	50	5.3
		16–100	35.60	33.10	32.00	49.81	1.30	0.061	6.75	2.40	<5.0	<2.5	50	5.8
11	Podzolized	0–65	65.05	22.55	12.40	52.96	4.37	0.148	11.28	8.05	>5.0	>2.5	100	5.2
	Zheltozem	65–150	32.20	35.40	31.40	54.57	1.49	0.088	5.22	5.45	<5.0	2.5	25	6.0
13	Krasnozem	0–15	66.3	13.70	20.00	52.27	2.54	0.118	5.40	6.05	>2.5	5.0	25	6.2
		15–130	40.60	36.30	23.10	51.95	1.46	0.081	4.70	5.35	2.5	2.5	25	6.2
17	Podzolized	0–33	58.00	37.20	15.20	54.10	2.40	0.113	3.84	7.00	>5.0	5.0	50	6.8
	Krasnozem	33–130	44.00	35.00	25.00	53.22	1.48	0.083	4.58	4.00	<5.0	2.5	25	6.2

the soils of the main tea regions of the eastern part of Futszyan' province have a pH of 4.7 to 6.4, while the degree of their saturation with cations is 28, 12 to 64, and 58%. This means that the soils here are generally favorable for tea culture. In the regions of the eastern part of Futszyan' province most of the soils are clays and sandy loams. In the thick zheltozems there are large amounts of organic matter, total nitrogen, and available phosphorus and potassium. Other types of soils are distributed here, too: podzolized krasnozems, krasnozems, violet soils, brown forest soils (Table 1).

TABLE 2

Chemical composition of the tea on various soils in the main tea regions of the province.

Soil	Section No.	Place sample taken	Ash %	Tea infusion %	Tannin %	Caffeine %	Raw protein %
Violet sandy loam	2	Village Khangan	5.0	27.43	11.65	1.518	29.25
Thick clayey zheltozem	3	“	4.0	26.36	11.05	1.345	24.81
Thin clayey krasnozem	7	Village Tsui-tsya	6.5	26.64	10.75	1.237	25.18
Thin clayey zheltozem	10	“	6.2	27.32	10.40	1.301	25.43
Thick clay-loam krasnozem	11	Village Mei-yan	4.5	23.50	9.30	1.114	31.43
Thick podzolized, sandy loam zheltozem	13	“	6.0	27.26	10.50	1.435	25.68
Thick podzolized, sandy loam krasnozem	17	Village Tan-yan	4.2	28.70	12.50	1.739	25.81

TABLE 3

Effect of various types of soil on the root system of two-year-old tea plants of the local variety, “Tsai-cha”[a].

Criteria for the development of the root system and of the above-ground parts of the tea plant (figures are in centimeters)	Types of soil[b]		
	Krasnozem	Zheltozem	Alluvial soil
Depth of penetration of roots	46.5	57.5	42.0
Horizontal distribution of root system	40 x 24	49 x 37	58 x 52
Diameter of main roots	1.2	1.3	1.75
Development of side and main roots	weak	medium	strong
Length of main roots	34	26	30
Plant height	62	52	69
Size of plant crown	43 x 38	47 x 42	52 x 47
Height of main stem	7	7.5	10
Growth	+	++	+++

[a] Figures given in the table are averages for 20 individual plants.

[b] Place of observation: Experimental tea field in Fu-an district.

The permeability of soils of different types is not uniform: for a thick, clayey krasnozem it is

60 to 72 mm. per hour; for a thick clay loam krasnozem it is 20 to 36 mm. per hour; for a thick clayey zheltozem, 50 mm. per hour; for sandy-loamy krasnozems and zheltozems, 300 to 360 mm. per hour. Clay loam or sandy loam with a permeability of 60 to 90 mm. per hour is required for the development of tea plants. Such a soil contains the necessary amount of nutrient substances. In the main regions of the eastern part of Futszyan' province, the soils generally answer these requirements, but the best of them are the krasnozems and zheltozems: the violet

TABLE 4

Development of the root system and above-ground parts of different varieties of two-year-old tea plants on one type of alluvial soil[a].

Criteria for the development of the root system and of the above-ground parts of the tea plant (figures are in centimeters)	Variety of tea[b]	
	"Tsai-cha"	"Tabai-cha"
Depth of penetration of roots	30	48
Distribution of root system	40 x 20	68 x 75
Diameter of main roots	1.0	1.8
Number of side and main roots	few	many
Length of main roots	23	36
Plant height	80	100
Size of plant crown	37 x 30	92 x 73
Height of main stem	15	18
Growth	++	+++

[a] Figures given in the table are averages for 20 individual plants.

[b] Place of observation: Experimental tea field in Fu-an.

TABLE 5

Comparison of developmental data of the root systems and above-ground parts of one-year-old tea plants of the variety "Tsai-cha" on thin and thick red soil[a].

Criteria for the development of the root system and of the above-ground parts of the tea plant (figures are in centimeters)	Type of krasnozem[b]	
	Shallow, clay loam	Thick, clay loam
Depth of penetration of roots	31	42
Distribution of root system	11 x 6	22 x 20
Diameter of main roots	0.6	0.8
Number of side and main roots	4	7
Length of main roots	26	29
Plant height	19	25
Size of plant crown	10 x 5.5	30 x 27
Height of main stem	0.5	5
Growth	++	+++

[a] Figures given in the table are averages for 20 individual plants.

[b] Place of observation: Experimental tea field in Fu-an.

TABLE 6

Development of the root system of two-year-old tea plants at different levels of the water table[a].

Criteria for the development of the root system and of the above-ground parts of the tea plant (figures are in centimeters)	Depth of water table, centimeters[b]	
	>185	<130
Depth of penetration of roots	48	14
Distribution of root system	68 x 75	26 x 18
Diameter of main roots	1.8	1.2
Number of side and main roots	many	few
Length of main roots	36	6
Plant height	100	54
Size of plant crown	92 x 73	20 x 13
Height of main stem	18	18
Growth	+++	+

[a] Figures given in the table are averages for 20 individual plants.

[b] Place of observation: Experimental tea field in Fu-an.

TABLE 7

Development of the root system of tea plants with various methods of cultivation[a].

Criteria for the development of the root system and of the above-ground parts of the tea plant (figures are in centimeters)	Variety of tea[b]			
	One-year-old "Tsai-cha"		Two-year-old "Tabai-cha"	
	Type of planting			
	set out	not set out	single row	double row
Depth of penetration of roots	99	85	34	30
Distribution of root system	187 × 140	147 × 86	54 × 46	40 × 30
Diameter of main roots	7	3.8	1.8	2.0
Development of side and main roots	good	weak	good	weak
Length of main roots	56	85	26	20
Plant height	136	166	70	61
Size of crown of plant	140 × 115	130 × 8	50 × 87	54 × 48
Height of main stem	38	52	8	7
Growth	++	+	+++	++

[a] The figures given in the table are averages for 20 individual plants.

[b] Place of observation: Experimental tea field in Fu-an.

and the brown forest soils are also favorable for tea culture.

The high quality of the tea of the eastern part of Futszyan' province is closely related to natural conditions and to the technical development of teas, but soil conditions remain one of the critical factors. The soils of the tea regions of the eastern part of Futszyan' province contain sufficient quantities of nitrogen, phosphorus, potassium and humic substances, and for this reason the quality of the green shoots of the tea plants produced on such soils is high (Table 2). An exception is constituted by some soils, such as podzolized krasnozems, in which there is 4.37% of organic matter, 0.148% total nitrogen, and less than 2.5 p.p.m. of available phosphorus. This leads to the accumulation in the tea leaves of large quantities of raw protein and lowers the quality of the black tea.

In order to raise the quality of the tea leaves in soils containing insufficient amounts of nitrogen, phosphorus, potassium and humus, there is further need for the application of organic and nitrogen fertilizers.

We have obtained data showing: the effect of different types of soils on the root system of the same variety of tea plant; the effect of a single soil on the root system of tea plants of the same and of different varieties of tea plants; how the root system of a tea plant develops with the water table at different levels; how different methods of management and of setting out young plants affect the root systems of tea plants of the same variety (Tables 3, 4, 5, 6 and 7). These data show that up to now there has been a series of unsolved questions connected with the ways of applying fertilizer, methods of management, and the selection of tea plants. The solution of these questions is very important for the further development of tea culture in the tea regions of the eastern part of Futszyan' province. For this reason it is very important that work be done on such questions as methods of cultivating tea, the application of fertilizers, the tea industry, and methods of treatment of tea.

In the eastern part of Futszyan' province are located the main tea regions of the Republic, where black bohea tea is produced. The development of tea production is of great economic importance for the mountain localities of Futszyan' province and for the Republic as a whole. Without doubt it exerts a positive effect on the socialist buildup of our country. According to the plan of agricultural development for Futszyan' province we must increase our tea harvest within 12 years to a size 10 times that of this year's crop. In order to fulfill this task we must direct our attention to such questions as a system of maintenance for tea plantations, the fight against soil erosion, the gradual conversion of old tea plantations into new ones, methods of applying fertilizers, increasing the production of shoots, and also the founding of new plantations. Under the leadership of the party and the government we will fulfill this difficult but important task.

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THE ROLE OF ANNUAL CULTIVATED PLANTS IN THE BALANCE OF ORGANIC AND MINERAL SUBSTANCES IN THE SOIL

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ONE of the reasons for creating a new system of soil cultivation was, for T. S. Mal'tsev, the very small size of the harvests in the Transural area of perennial grasses, the basis of meadow crop rotation. At the collective farm "Zavety Lenina" in thirteen years the grass crops amounted to 11.2 centners per hectare of hay, two centners less than the quantity of spring wheat produced during the same period of time (4). Thus, doubt was cast on the exclusive role of perennial grasses in increasing the fertility of chernozems in the arid climate of the Transural area. For the purpose of increasing soil fertility, T. S. Mal'tsev suggested the use not only of perennial grasses, but chiefly of annual cultivated plants: spring wheat, vetch-oats mixtures, annual legumes. Recognition that annual farm crops can increase soil fertility when a certain method of soil cultivation is used with all crops is considered to be the theoretical basis of Mal'tsev's system. In this connection it is necessary to clarify what quantity of which nutritive substances are left in the ground with the roots and stubble of annual crops after harvesting and also what quantities of which substances are removed from the soil with the grain, straw and hay crops.

In the present paper data are given on the content of nitrogen and of the mineral elements of nutrition in the root systems and above-ground portions of the basic crops of Mal'tsev's crop rotation. Consideration is also given to the distribution and development of root systems of annual plants with various methods of soil cultivation.[1]

Purpose of the Investigation

Work in the field was begun at field outposts of the expedition of the Academy of Sciences of the USSR, sites of which were selected on the most widespread soils of the collective farm, chiefly on leached chernozems of different thicknesses and partly on the salinized chernozems found under unique natural conditions (5). These were the basic fields for T. S. Mal'tsev's crop rotation with a cover of spring wheat: on deep fallow (subsurface plowing at a depth of 50 cm.)—experiment 2, section 110; with disking the first year—experiment 3, section 114; with disking the second year —experiment 7, section 107; with disking of land 20 years in fallow. To these corresponded the control-field sowings of spring wheat on the usual fallow (plowed 20 to 22 cm. deep with inversion of the furrow slice): section 100; fall-plowed for one and two years—sections 104 and 116; and the usual plowing of land 20 years in fallow.

The terrain of the collective farm was gently rolling plain with enclosed depressions and slight elevations. The fields were very large blocks surrounded by forests and having natural boundaries. The ground water was at a depth of 3.6 to 6 m. The natural outlets for the ground water were about the same everywhere and were slightly salinized. Dry residue was 0.3 to 0.4 g. per liter (Table 1).

In both cases the water was hard (the alkaline earth elements calcium and magnesium predominated in the dry residue). The slightly alkaline reaction made possible the solution of SiO_2. The presence of sodium in the water showed the weak salinization of these soils. Sesquioxides (Fe_2O_3, Al_2O_3), titanium and manganese in the ground water were not detectable by the usual chemical methods.

The soils of the collective farm are notable for their high potential fertility. Often medium-thick chernozems were encountered (horizon A = 30 to 36 cm., sections 114 and 110) with a humus content in the upper layer of 8 to 10%. Most of the content of organic matter was in the top 50 to 60 cm. According to N. N. Nikanorova, the amount of humus in the top one-meter layer of

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[1] These data were produced by field and experimental investigations during 1953, 1954, and 1955 on the collective farm "Zavety Lenina," Shadrinsk district, Kurgan region, by a composite delegation from the Academy of Sciences of the USSR (Director, Academician I. V. Tyurin).

TABLE 1

Chemical composition of the ground water from natural springs on the land of the collective farm.

Date sample taken	Location	Salinity mg./l.	As percentage of dry residue							
			CaO	MgO	SiO_2	Na_2O	K_2O	P_2O_5	SO_4	Cl
8/30/54	Panova Loga Spring	275	31.71	11.99	7.13	3.63	1.32	0.02	—	traces
same	Spring on the Popovshchina tract	425	29.12	11.84	5.46	3.61	1.57	0.05	traces	—

these soils was about 430 metric tons per hectare, of which 80% was in the top one-half meter.

Effervescence from HCl began at a depth of 86 to 90 cm. The parent soil material was a yellow light-brown carbonate clay loam, gleyed in places and underlain by sand.

With respect to mineralogical composition, the soils at the field outposts closely resembled each other. The upper horizons generally had clay minerals (up to 80 to 90%) ; the sand content increased with depth. In the mineral composition there was a predominance of quartz and feldspars, among which were both potash (microcline) and lime and soda (plagioclase) types; the latter was already muddy ("pelitized"). Of the accessory minerals the following were detected in all horizons: hornblende, pyroxenes, zoisite, epidote, and glauconite. The large mineral grains had a corrugated angular form, showing that the minerals had not been transported far, while the presence of well-preserved pyroxenes (which are comparatively unstable in soil) showed that the minerals had not undergone any considerable changes in their present location. Thus, the composition and comparatively fresh appearance of the minerals also showed the presence in these soils of a considerable supply of nutrients.

Sampling Plants by the Monolith Method

Samples of spring wheat and annual legumes, vetch (with oats), lentils and peas were taken in the field together with the soil as a monolith. To compare the roles of annual plants and perennial grasses, similar work was carried out on two-year-old clover. To remove the soil monolith with the plants, a section 50 cm. deep and 80 cm. wide was dug out. Two rows of wheat(or other plants) remained in the middle of the soil monolith, which was placed in a box with a sliding wall. The dimensions of the box were 25 x 25 x 40 cm. high. The samples were taken in triplicate and on the same day they were brought to a river and washed with a thin stream of water from a pump. To wash free the root systems of a single soil block required about 100 vedros (= 325 gallons) of water. In this process the soil was washed off onto a strainer to avoid losing any roots which might be broken off. The soil was transferred in small portions from the strainer into a basin of water and carefully stirred and decanted several times onto a clean strainer. This operation made it possible to collect both the thinnest live roots broken off the general root system of the plants and also the old organic residue. The washed samples were sorted by hand and freed from extraneous particles such as rotten remains and roots of weeds (all these were weighed separately) and dried in the sun.

Sampling plants by the soil monolith methods has substantial advantages in ash analysis. It makes possible washing the roots of the whole freshly-dug plant. This does not involve any noticeable washing away of nutritive substances from the plant since the live plant, being in a state of turgor, retains the dissolved substances within its cells. Use of this method also allows production of enough roots for analysis and for calculating the amount of roots per hectare in a 40 cm. layer of soil.

Amount of Root Residue in T. S. Mal'tsev's Crop Rotation

Observation of the whole series of washed root systems of annual plants makes it possible to conclude that wheat roots develop better with disking than with the usual plowing because they occupy a greater volume of soil. This was especially noticeable in the dry year of 1953. When the ground had been disked to a depth of 8 cm. the old roots remained beneath and it was often possible to see the new roots growing among the old, obviously using the nutrients of their forerunners.

With respect to the quantity of roots of annual crops, we noted what a very small amount of this

TABLE 2

Quantity of root residues of spring wheat with different methods of soil tillage.

Date sample taken	Kind of wheat	Previous tillage	Quantity of live roots, g./monolith			Live wheat roots, ctnrs. per ha.	Quantity of old roots, g./monolith			Old roots, ctnrs. per ha.	Total root residue, ctnrs. per ha.
			0–40 cm.	40–80 cm.	Total		0–40 cm.	40–80 cm.	Total		
Aug. 24–31, 1954	Mil'turum 553	1 year of disking	4.21	—	4.21	6.74	1.09	—	1.09	1.74	8.48
same	Lyutestsens 758	2 yrs of disking	3.15	—	3.15	5.04	1.32	—	1.32	2.11	7.15
same	same	ordinary fallow	3.99	—	3.99	6.38	1.95	—	1.95	3.12	9.50
same	same	deep fallow	4.53	0.77	5.30	8.48	2.25	0.43	2.68	4.29	12.77
same	same	usual tillage of virgin soil	5.90	1.04	6.94	11.10	3.82	0.88	4.70	7.52	18.62
same	same	disking of virgin soil	8.69	0.23	8.92	14.27	12.50	0.52	13.02	20.83	35.10
Aug. 17, 1955	Lyutestsens 758	deep fallow	6.10	1.80	7.90	12.85	4.70	1.30	6.00	9.60	22.45
same	same	same	6.60	1.57	8.17		5.70	0.63	6.33		
Aug. 20, 1955	same	ordinary fallow	4.31	1.50	5.81	9.07	11.20	0.55	11.75	18.80	27.87
same	same	same	4.48	1.05	5.53		11.60	0.15	11.75		
Aug. 22, 1955	same	disking of virgin soil	4.20	3.70	7.90	13.49	—[a]	1.40	—		
same	same	same	4.66	4.30	8.96		—	1.20	—	—	—

[a] The residues were severely contaminated with mineral particles which it did not appear possible to remove by any method known to us.

there was in 1953—from 6 or 8 to 12 centners per hectare of clean wheat roots, as shown by the following data:

		In grams per monolith	In centners per hectare
Lyutestsens 758 (August 3)	with usual plowing	2.00	3.20
same	with deep fallow	4.00	6.40
Mil'turum 553 (July 20)	1st year plowing	7.05	11.28
same	1st year disking	7.90	12.64
Mil'turum 553 (August 1)	2nd year plowing	3.80	6.08
same (July 22)	2nd year disking	5.60	8.96

Collaborators from the Institute of Plant Physiology, Academy of Sciences, USSR, made a special study of the volume and weight of the root systems. Our approximate calculations coincided with their data (see the account by N. N. Satarova for 1953). To convince ourselves of the correctness of our ideas concerning the small quantities of wheat root remains and especially of live roots, we undertook in 1954 and 1955 careful determinations of live wheat roots and of old organic residues at depths from 0 to 40 cm. and from 40 to 80 cm., in which soil monoliths with wheat roots were also removed (Table 2).

Thus, it was established that the quantity of live roots of spring wheat in the soil layer from 0 to 80 cm. does not exceed 0.9 to 1.3 metric tons per hectare. Similar results[2] were given in the summary report of the group from the Institute of Plant Physiology, Academy of Sciences, USSR, in 1957 (3). The total quantity of wheat roots did not exceed 0.9 to 1.2 metric tons per hectare, according to the physiologists' data. It is of interest that in both cases during the course of three years there were removed from the soil, washed and counted about 500 soil monoliths with spring wheat at the stages of seed formation, ripening, and waxy maturity.

On virgin tracts, of course, somewhat more roots were found, especially with disking of the virgin soil. At a depth of 40 to 80 cm. there were very few roots, about 0.36 centners per hectare on disked virgin soil and 1.66 centners per hectare of wheat roots on plowed virgin soil. Old but undecomposed roots were especially numerous on disked virgin soil, amounting to 20.83 centners per hectare, while on the usual crop rotation tract they were 2 to 4 centners per hectare.

It was also important to establish the quantity of roots and stubble after the harvesting of annual leguminous crops, as one of the links in Mal'tsev's crop rotation (Table 3).

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[2] This includes quantities of roots undergoing humification and root secretions, which were the subject of a special study.

TABLE 3

Amount of organic residue from annual leguminous plants.

Date sample taken	Crop	Previous tillage	Quantity of live roots		Stubble ctnr./ha.
			In grams per monoliths 0–40 cm.	centners per ha.	
July 28, 1953	Peas	1st year of disking	2.90	4.64	—
July 28, 1954	Peas	1st year of disking	3.80	6.08	12.24
July 29	Vetch with oats	same	4.90	7.84	9.41
July 31	Lentils	same	4.50	7.20	9.33

TABLE 4

Amount of root residue on virgin land.

Date sample taken	Vegetation	In g./monolith			In metric tons per hectare	Hay crop ctnr./ha.
		0–40 cm.	40–80 cm.	Total		
Aug. 9–11, 1955	Meadow vegetation (water table, 2.5–3 meters)	90.20	4.10	94.30	15.35 (of which 4.67 ctnr./ha. 40–80 cm. deep)	40
		123.28	1.96	125.24		
		100.21	2.65	102.86		
		58.46	2.95	61.41		
Aug. 12–17	Meadow-steppe vegetation (water table below 6 meters)	112.15	none	112.15	19.31 (of which 1.41 ctnr./ha. 40–80 cm. deep)	20
		87.90	1.15	89.05		
		150.70	0.70	151.40		
		128.50	0.80	129.30		

To compare the quantity of roots of annual crops plants with the supply of root residues in virgin land, soil monoliths were taken with plants from virgin tracts having meadow and meadow-steppe vegetation. The results of this with quadruplicate sampling are shown in Table 4.

With perennial plants, and particularly with clover, in the dry year 1953 (when the harvest of 2-year-old plants was 12 centners per hectare) the root systems were very weakly developed and the quantity of roots per hectare was only 3.2 centners (Fig. 1). This fully confirms Mal'tsev's belief that in the dry Transural climate, perennial plants cannot raise the fertility of the soil. When there is a very small crop of clover above ground, only a small quantity of root remains is left in the soil. If increased water requirement is used as a criterion, clover loses its advantage over annual plants. In the rainy year of 1954 (unusual for the Transural) clover developed better (the crop was 40 centners per hectare of hay), but the root system of such clover differed little by weight from the root system of wheat. In one soil monolith the quantity of clover and wheat roots was:

	In grams	In centners per hectare
Two-year-old clover		
In dry 1953	2.20	3.20
In rainy 1954	6.29	10.00
Wheat, first year disking		
In dry 1953	7.90	12.64
In rainy 1954	8.69	13.90

Thus, under Transural conditions and especially in dry years such as 1953 there is a relative increase in the role of annual plants, particularly spring wheat and annual legumes, in the renewal of organic matter in the soil. Because of the selective absorptive capacity of plants they accumulate mineral elements and, on dying, leave them in the upper soil horizons with the roots and stubble (7).

The effect of accumulating mineral elements should be especially clearly developed with disking, when the root systems develop at a faster rate and up to 70% of the wheat roots (2) are concentrated in the top 10 cm. of the soil.

It should be noted that this "accumulation" of mineral elements represents only their redistribution and concentration in the root layers of the soil due to the action of the plants. True accumulation in the soil occurs only with the nitrogen assimilated by legumes.

How Plants Were Analyzed

Before analysis the dry plant material was inspected under a binocular magnifying glass to ensure the absence of soil particles. The roots were inspected with special care. The samples tested were cut up fine with scissors into pieces 3 to 5 mm. long from which an average sample was taken for analysis; the roots were analyzed whole. Before analysis the wheat grains were ground to a fineness of 0.1 mm. in an agate mortar. For ash analysis we used 15 to 20 g. of the above-ground parts, 25 g. of grain, and 8 to 10 g. of roots. Ashing was carried out by the dry method in a muffle furnace at 400° C. until a constant weight of the ashes was reached, usually in about 5 days. Determination of the individual elements was carried out in accordance with the systematic procedure for ash analysis. Removal of the amorphous silicic acid, which is usually difficult for grasses in alkaline solution, was carried out by treatment with 5% KOH for two hours on a water bath followed by boiling for 10 minutes. The content of individual elements in the ash was calculated as a percentage of the pure, carbonate-free ash (without CO_2 and mechanical admixtures). Determination of total nitrogen was done by heating separate aliquots with concentrated sulfuric acid (Kjeldahl method).

Nitrogen Content and Mineral Elements in Roots and Above-Ground Parts

Nitrogen and mineral element analysis of the roots of wheat and annual legumes showed that: 1. In wheat root ash (Tables 5, 6, and 7) silica (up to 40 to 62%) and potassium (up to 16 to 24%) predominate; by the end of the growing period there are increases in the quantity of iron and especially of aluminum (9%); in wheat grown on deep Mal'tsev-type fallow, the nitrogen content is somewhat higher than with other types of tillage. 2. In the roots of annual legumes (Table 8), which have a relatively high total ash content (9 to 13%), there is predominance of SiO_2 (20%), potassium (especially in lentils), calcium, and sulfur (10 to 14%). The nitrogen content reaches 2 to 3%.

In the ash of the above-ground parts of the wheat plants (as with all grasses), potassium and silica are the most abundant. There is a particularly large quantity of silica in wheat straw—up to 71%—at the time of cutting. In the grain the most abundant elements are phosphorus (up to 51%) and potassium (up to 28%; Table 7). Potassium and calcium are most abundant in the ash of the above-ground parts of annual legumes (Table 8). Of special importance is the accumulation of nitrogen by legumes: vetch, lentils, and peas are distinguished by their high nitrogen content, not only in the roots but especially in the above-ground parts (up to 4%).

Removal of Elements Necessary for Plant Nutrition

Calculation of the amount of nitrogen and mineral elements in wheat roots in 1953 showed a very small concentration of them by the root residue in the upper 40 cm. layer of soil: nitrogen, up to 12 kilograms per hectare; phosphorus, up to 2.3; potassium, up to 16; magnesium, up to 2.6; and sulfur, up to 4.2.

According to the 1954 data, along with the roots and stubble, the following amounts of these

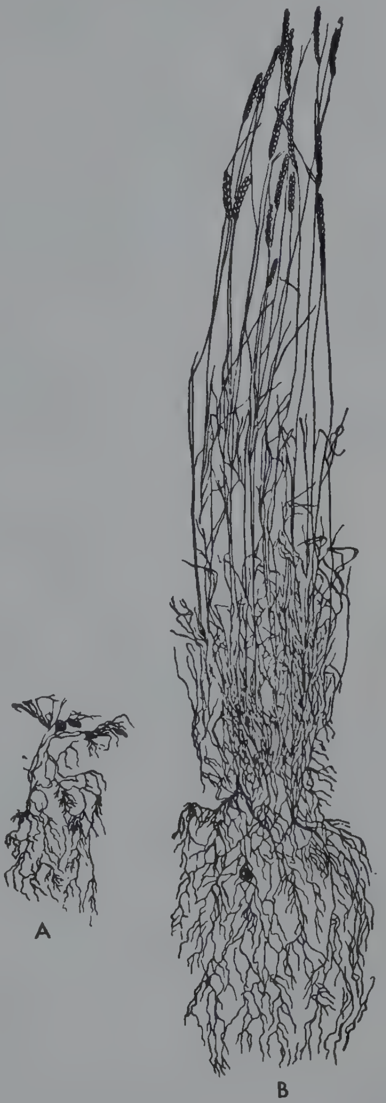

FIG. 1.—Comparative pictures of the root systems of clover and wheat in the dry year of 1953. (*a*) Two-year-old clover after cutting July 27. (*b*) Wheat planted on first year of disking, at the stage of seed formation on July 20.

TABLE 5

Ash analysis of Lyutestsens 758 spring wheat sown in 1953 on deep fallow and with the usual tillage.

Sample and date taken	Stage of development	N as % of dry material	Clean ash, %	As percentage of clean, carbonate-free ash													
				SiO_2													
				In HCl extract	In KOH extract	Total	Fe_2O_3	Al_2O_3	TiO_2	P_2O_5	CaO	MgO	MnO	K_2O	Na_2O	SO_3	Total
1. *Deep fallow*																	
Above-ground parts																	
July 1	tillering	4.13	11.32	8.12	23.67	31.79	0.07	0.03	none	5.32	6.90	3.18	0.04	46.31	0.20	4.54	98.38
July 18	seed formation	3.19	7.54	4.62	32.35	36.97	0.08	0.09	"	6.58	6.35	4.29	none	36.78	0.33	4.33	95.80
Aug. 3	ripening	1.32	5.01	1.99	44.80	46.79	0.21	0.34	"	6.67	7.39	3.71	"	21.88	none	5.07	92.06
Roots																	
July 1	tillering	1.79	11.07	2.61	60.20	62.81	2.23	3.79	traces	2.67	5.55	4.30	0.16	9.12	0.76	3.27	94.66
July 18	seed formation	1.29	7.67	3.47	50.84	34.31	1.82	4.31	"	3.04	6.87	5.06	0.14	13.59	1.38	5.79	96.31
Aug. 3	ripening	1.35	7.61	7.89	36.33	44.22	4.35	9.09	"	2.89	7.27	3.63	none	15.23	5.09	5.71	97.48
2. *Fallow with usual tillage*																	
Above-ground parts																	
Aug. 3	ripening	1.51	4.43	0.93	43.19	44.12	0.14	0.45	"	7.21	5.33	5.31	0.05	23.88	0.74	6.82	94.05
Roots																	
Aug. 3	ripening	0.93	5.97	5.44	51.25	56.69	2.95	5.98	"	3.09	7.48	4.39	traces	12.65	3.31	6.52	103.06

TABLE 6

Ash composition of spring wheat Mil'turum 553 (dry year 1953).

Previous tillage	Stage of development and date	N as % of dry material	Clean ash, %	As percentage of clean, carbonate-free ash													
				SiO_2													
				In HCl extract	In KOH extract	Total	Fe_2O_3	Al_2O_3	TiO_2	P_2O_5	CaO	MgO	MnO	K_2O	Na_2O	SO_3	Total
Above-ground parts:																	
Disking first year	tillering July 4	2.96	7.32	4.87	15.28	20.16	0.14	0.17	none	8.45	6.05	2.26	none	57.66	none	5.73	100.62
same	seed formation July 20	1.67	4.87	7.53	26.64	34.17	0.14	0.15	"	6.93	5.13	3.00	"	45.59	"	5.06	100.17
Usual tillage	same	1.45	4.85	2.98	31.33	34.31	0.10	0.24	"	7.90	4.78	3.93	0.04	38.79	0.72	5.17	95.98
Disking first year	seed formation July 22	1.77	6.00	5.50	35.38	40.88	0.21	0.28	"	6.39	6.12	2.82	none	38.36	none	4.97	100.03
Usual tillage	same	1.61	7.79	6.73	38.52	45.25	0.18	0.37	"	5.87	6.77	2.10	"	36.50	traces	3.71	100.75
Roots:																	
Disking first year	tillering July 4	1.80	5.52	4.92	35.62	40.54	1.36	3.00	traces	7.69	5.25	5.42	0.06	28.93	none	5.23	97.48
same	seed formation July 20	0.89	5.57	5.10	36.08	41.18	2.40	6.33	"	3.37	7.61	3.93	none	24.39	2.66	6.04	97.91
Usual tillage	same	1.17	7.28	5.38	37.80	43.18	2.91	7.40	"	2.99	5.71	3.36	0.12	18.37	3.83	5.27	93.14
Disking second year	seed formation July 22	1.12	8.06	7.44	32.91	40.35	4.71	6.70	"	2.93	9.37	2.89	none	14.71	4.63	6.24	92.53
Usual tillage	same	1.07	9.02	6.02	41.11	47.13	4.32	8.87	"	2.96	6.63	2.57	"	14.63	3.38	5.51	96.00

TABLE 7

Ash composition of wheat at the stage of waxy ripeness (rainy year 1954).

Sample and date taken	Previous tillage	Part of plant	N as % of dry material	Clean ash, %	As percentage of clean, carbonate-free ash													
					SiO₂													
					In HCl extract	In KOH extract	Total	Fe_2O_3	Al_2O_3	P_2O_5	CaO	MgO	MnO	K_2O	Na_2O	SO_3	Total
Mil'turum 553, August 31	Disking first year	Grain	1.73	2.00	1.15	5.51	6.66	0.63	1.19	47.54	2.85	12.25	0.21	28.36	traces	0.83	100.52
		Straw	0.29	7.06	1.62	69.30	70.92	0.63	0.21	1.55	4.15	2.05	0.34	14.64	0.15	2.46	97.10
		Root	1.02	7.60	3.93	54.34	58.24	2.71	6.46	2.64	7.88	2.99	none	8.60	1.39	3.56	94.47
Lyutestsens 758, August 24	Disking of 20-year fallow	Grain	2.03	1.82	none	1.53	1.53	traces	0.33	48.67	2.87	11.66	0.28	28.20	0.20	0.22	93.96
		Straw	0.40	5.25	1.12	60.43	61.55	"	0.16	1.76	2.11	1.61	0.04	19.85	0.85	3.72	91.65
		Root	0.79	9.40	3.57	67.34	70.91	1.89	4.01	1.66	7.12	2.56	0.14	2.79	1.44	2.90	95.42
Lyutestsens 758, August 24	Plowing of 20-year fallow	Grain	2.21	1.79	0.20	2.88	3.08	0.13	0.28	51.16	2.67	13.13	0.28	27.42	0.31	0.17	98.63
		Straw	0.51	6.44	1.15	64.20	65.35	traces	0.18	1.80	2.71	1.84	0.02	19.18	0.45	4.07	95.60
		Root	0.67	8.47	4.38	58.10	62.48	2.12	4.75	1.65	8.60	3.82	0.10	2.55	2.14	4.19	92.40

TABLE 8

Ash composition of clover and annual legumes—vetch with oats, lentils and peas.

Date sample taken	Crop	N as % of dry material	Clean ash, %	As percentage of clean, carbonate-free ash														
				SiO₂														
				In HCl extract	In KOH extract	Total	Fe_2O_3	Al_2O_3	P_2O_5	TiO_2	CaO	MgO	MnO	K_2O	Na_2O	SO_3	Total
	Above-ground part:																
July 8, 1953	2-year-old clover (one cutting)	2.55	5.81	0.43	2.08	2.51	0.13	0.07	5.45	none	39.31	10.17	none	39.37	0.09	3.08	100.18
July 28, 1954	Peas	4.21	7.94	1.01	1.50	2.51	0.23	0.60	10.14	"	21.01	11.41	0.06	36.14	2.08	8.56	92.74
July 29, 1954	Vetch with oats	2.86	6.93	6.45	1.47	7.92	0.13	0.28	7.81	"	32.85	6.14	none	33.86	1.97	4.66	95.62
July 31, 1954	Lentils	2.79	5.03	0.96	1.56	2.52	0.19	0.14	14.30	"	27.14	8.13	0.09	35.75	0.32	4.67	93.25
	Roots:																
	2-year-old clover (one cutting)	1.53	3.56	3.46	7.36	10.82	1.11	2.61	7.52	none	13.95	16.54	none	33.67	0.63	6.46	93.31
	Peas	2.18	10.46	12.76	14.40	27.16	2.88	6.58	3.79	traces	12.59	4.10	0.08	13.55	12.99	10.26	93.98
	Vetch with oats	2.31	9.11	7.83	12.26	20.09	2.29	6.93	5.31	"	12.00	8.67	0.08	26.61	1.31	10.02	93.31
	Lentils	2.90	12.76	8.65	12.44	21.09	2.82	7.54	5.93	"	14.99	7.12	0.13	12.82	2.13	13.14	87.71

elements (in kilograms per hectare) remained in the soil:

	N	P	K	Ca	Mg	S
Spring wheat at 8 to 13 centners per hectare of roots and 15 to 25 of stubble	18	4	31	11	6	9
Annual legumes at 6 to 7 centners per hectare of roots and 9 to 12 of stubble	38–60	7–12	30–40	18–28	6–15	7–16

At the same time the harvest removed from the soil the following quantities of these elements (in kilograms per hectare):

	N	P	K	Ca	Mg	S
Spring wheat: Grain crop 21.26 centners per hectare (1953) and 23.5 to 24.8 (rainy 1954) with Lyutestsens 758; straw from 32 to 60 centners per hectare[3, 4]	42–80	20–28	41–84	9–12	8–11	5–15
Annual legumes (with hay crop of 40 centners per hectare)	100–148	19–29	60–100	15–32	40–80	8–24

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[3] Calculation of the stubble was carried out by the generally accepted method of test areas after harvesting.

[4] Here the nitrogen and phosphorus were removed chiefly with the grain, the potassium and magnesium predominantly with the straw but also with the grain, the calcium and sulfur mostly with the straw.

Here is what these facts mean: The quantities of the basic elements of mineral nutrition (phosphorus, potassium, magnesium, sulfur) and of nitrogen remaining in the soil with the roots and stubble after the wheat harvest has been collected do not, regardless of kind of tillage, exceed the quantities of these elements removed with the harvest. Nor can the quantities of these elements remaining in the soil compensate for the loss in the soil through the harvest.

We must also remember that grasses do not fix nitrogen from the air. They can obtain it only from the soil at the expense of the decomposition of humus and the nitrogen of fertilizers, since other sources of nitrogen, that is, precipitation (4 kilograms per hectare per year), seeds (3 kg.), and a certain amount which accumulates in the soil due to azotobacter activity are insignificant (9). For example, a wheat crop of 20 centners per hectare removes from the soil up to 50 kilograms of nitrogen per hectare which, in the absence of nitrogenous fertilizer, corresponds to the decomposition of about one metric ton of humus, that is, 1/200 of the humus content of the top 20 cm. of chernozem. Our data showed that wheat removed up to 80 kilograms of nitrogen per hectare, and no nitrogen at all was returned to the soil in the form of manure or straw. Consequently, in producing the wheat crop nitrogen was expended generally along with the decomposition of the humus.

A special role in the accumulation of soil nitrogen belongs to the legumes, the annual forms of which we believe are able to retain in their roots and stubble significant quantities of nitrogen—up to 60 kilograms per hectare—while an even greater quantity of nitrogen is contained in the removed crop. However, how much nitrogen is assimilated by legumes from the atmosphere and how much from the soil still remains unknown.

Conclusion

In the central Transural in dry years, annual plants, especially spring wheat, leave in the soil more organic residue than does clover even at its lowest yield. However, the organic residue from annual grass crops which is left in the soil and on its surface (stubble) and the nutritive substances which it contains can provide only a small part of the nutritional requirements of the plants of the subsequent crop if it is a good one (about 20 centners per hectare). The high yields of wheat and other crops now being obtained on the collective farm "Zavety Lenina" are generally assured by the potential reserve of nutritive substances in the chernozems in which these reserves are very large (430 metric tons of humus per hectare). The new system of soil tillage worked out by Mal'tsev and involving destruction of weeds evidently causes more active mobilization of these reserves than does the usual plowing to a depth of 20 to 22 cm.

The inclusion in crop rotations of annual legumes, because of the way they assimilate nitrogen from the air, makes it possible to obtain good wheat harvests and at the same time to use the reserves of humus more economically.

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Discussion

SOME QUESTIONS OF THE AGRONOMIC CHARACTERIZATION OF LAND RESOURCES FOR LAND USE PURPOSES

G. M. Meerson

When powerful agricultural engineering techniques are used, the organization of an area for the most productive work with these techniques is of great importance. Much has been written on this subject. Chief among the measures is recognized to be the creation of large-scale fields with very long borders and correct configuration. Mechanization has made necessary the enlargement of fields of collective farms, the new organization of arable lands, and other measures in the internal structure of collective and state farms.

Questions of the organization of an area with respect to these requirements have created a series of new tasks for specialists in mechanization, agronomy and land use. The agrotechnical and technological heterogeneity of arable land resources is a phenomenon of the widest occurrence in nature. Its significance has clearly not been sufficiently studied by specialists in mechanization in working out the requirements for the organization of a land area. The question was lost sight of in experimental, theoretical agricultural engineering. The land use specialists were directly confronted with these questions when they were obliged to "harmonize" the mutual requirements of the specialists in mechanization, agronomy, and animal husbandry in organizing the areas of collective and state farms. The pattern of distribution of lands in enlarging state farms proceeded primarily on the principle of contiguity of boundaries in an effort to abolish scattered holdings of land and to straighten the land use boundaries. In the course of land use procedures, plots and sections of crop rotation land were enlarged in order to organize large fields best suited to the requirements of mechanization. In this operation soil and organizational-economic conditions had to be considered. However, in solving this question, the soil surveys in most cases either did not take place at all or used old data and small-scale soil maps not appropriate for production requirements. Soil surveys were replaced by the so-called agro-economic surveys under the direction of the land use specialist. The allocation of rotated crops and their fields was carried out without regard to relief in the absence or unavailability of data from topographic surveys.

Where the soil was more or less uniform, as in the plains regions, solving the consolidation of crop rotation sections and fields could to some degree satisfy the requirements of mechanization and agronomy in the organization of the area. In regions with nonuniform soils the task was much more complicated. This question should be dealt with in more detail.

If crop rotation sections and fields are created in areas of complex relief and with a patchwork of soil types, and if all arable land is included in the crop rotations, no single solution of the question can be recommended. It is considered desirable to form crop rotation sections and fields on the basis of their uniformity, in order to provide uniform conditions for the rotated crops. But more or less uniform conditions within large crop rotation sections may exist only under uniform conditions of relief and soil type on plains, as may be found in the piedmont regions of the North Caucasus, the Ukrainian steppes, and in some regions of the area east of the Volga and the Urals.

In introducing crop rotations where the soil types are not uniform, it is permissible to form separate fields on the principle of agrotechnical uniformity within each field. Here the individual fields in the crop rotation may show a fair amount of variation in soil and agrotechnical conditions. For this reason, after a few years of rotation, crops with particular requirements will be distributed on fields regardless of uniformity, although with poorer soil conditions. This may lead to considerable fluctuations of the crops in rotation years if the order of the crops in time and area is strictly adhered to. In order to decrease fluctuations in the crops from one year to another, the recommendation is made, in contradiction to the principle stated above, that crop rotation fields be projected (formed) in such a way that each contains more or less the same proportion of soil of different productivities. In crop rotations set up on the principle of agrotechnical uniformity within each field, the question generally is reduced to working out differentiated agricultural methods for each separate field of rotated crops. When each field contains a mixture of soil types, the differentiated agricultural methods should be worked out to conform with the special features of the individual plots within the field.

As may be seen, these principles of organization of a crop rotation area assume high-level treatment of these very important questions of differentiated agricultural practices in accordance with the special natural conditions of each individual plot of the crop rotation section and also as related to the role of the individual predecessors and special biological features (requirements) of the individual crops. Here we must not overlook any real possibility for realizing the planned agricultural practices under actual farming conditions. When crop rotation areas are to be organized, the complete inadequacy of the general information on the productivity of the land resources based on data from soil surveys is to be regretted. The crop rotation practices to be carried out are noted only in very general terms, often without considering whether or not they can be carried out. The introduction of crop rotations is based on strict observance of the principle of the sequence of crops in time and space or, less often, only in time. It should be recognized that this principle cannot always be justified when there is great variation of soils and crops presenting nonuniform requirements for soil conditions.

The effectiveness with which modern powerful techniques are used depends directly on the size of the fields and their configurations. The demands for laying out fields in the shape of large blocks with long borders are, in practice, relegated to the last plan to be considered in the agrotechnical series. Furthermore, we cannot consider the question of the delimitation and formation of crop rotation sections and fields as sufficiently studied from the point of view of technique and production (that is, agricultural practices and mechanization) or of economics. This central question of organization for arable land use in different zones of the country for big farms with varied soils has not been studied experimentally.

Among the numerous causes for failure in carrying out land use projects and in introducing crop rotations are many facts which can be explained by incorrect practical decisions concerning questions of the assembly of crop rotation sections and fields. Among these is the decision to include *all* arable land in crop rotation fields regardless of their uniformity or differences in access or configuration. In other words, soil variations appearing to be more or less genetically uniform are combined into large blocks to create large fields.

From the point of view of agricultural methods, *the enlarging of fields at the expense of neighboring tracts is acceptable only when the productivity differences between them can be spanned by using differentiated agricultural practices which are still within the capabilities of the particular farm.*

Differences in fertility within individual sections which are more or less uniform in relief and texture may be explained by various causes: nonuniformity of thickness, of tillage of the surface layer, of acidity, or of fertilization of the individual plots. Uneven drainage or accumulation on the soil surface of water from rain or melting snow or differences in the amount of weeds on different plots may sometimes be explained by incorrect tillage in the past. Small differences in the relief do not always cause noticeable differences in the time of the appearance of soil mellowness or in the passage of plants through the stages of development. Under these conditions there is no basis for enlarging the neighboring tracts, since all these differences may be spanned by differential farming measures without any complicated changes in the use of the modern means of mechanization on such fields.

It should be especially emphasized that in carrying out mechanical tillage of the soil, especially in plowing, soil uniformity for mechanical tillage purposes is of very great importance in meeting the required standards of quality. This fact is often ignored in enlarging fields, as if largeness were a goal in itself which determines the effectiveness of the use of the machine and tractor pool regardless of the productivity of soil tillage or of the final productivity of the agriculture as determined by the harvest. Differential farming measures assume the use of selected methods in accordance with the peculiarities of each plot within the borders of each field having special but nonuniform features. With respect to mechanical tillage of the soil, this means subdividing the field into smaller parts and choosing such times and tools as agree best with the soil consistence at the moment of tillage. In this connection, discretion should also be exercised in the choice of time and method of sowing, care of the plants, and harvesting. It is not difficult to see that serious contradictions are created between the requirements for increasing the productivity of the machine and tractor pool when cutting out large fields, and the requirements of farming practices when nonuniform fields must be farmed.

This question has also not been studied experimentally.

It is possible that when different kinds of mechanized work are carried out at different times, the question of the size of the fields and the length of the borders may be solved in different ways. After the harvest of grain crops the state of the upper soil layer very often makes possible the union into large sections adjoining tracts having different soils, not only at the time of undercutting the stubble but also at fall plowing. Under conditions of increased moisture, especially in spring, differences in soils throughout the entire section most often lead to negative results when it is all tilled at once. Every agronomist knows that only harmful results can come of simultaneously tilling various fields when the individual tracts on them contain soils differing in tilth. Especially harmful results are entailed by plowing soils of different texture when one large plowed section may contain not only tracts with mellow soil but a considerable number of tracts with dry or, on the contrary, moist compacted soil which is difficult to shatter. It is very difficult to equalize such plots, that is, to span the physical difference between them. They need different tillage depending on whether they are behind or ahead of the season. When working on a large scale it may be possible to ignore the basic tillage requirements along minor contour changes. But such tillage limits the quality of all subsequent operations and, correspondingly, the quality of the harvest.

In carrying out land use planning, the answer to individual questions of improving certain large sections is related in some cases to the need for carrying out formal soil improvement projects. However, the decisions on projects are often made without taking into account the delay such work would cause. This is related to the assembly of large fields to include tracts requiring comparatively complex and radical improvement and to reshaping fields and straightening boundaries. Such "concessions" often occur when there are no detailed soil surveys or topographic information. And finally, on such fields the use of differential agricultural practices becomes more complicated; even the basic requirements for agricultural practices are not observed; and the crop remains for a long time at a low level which often does not even justify its cost.

It seems to us that it is time to analyze and reconsider the question of the rational dimensions of fields, boundaries, and crop rotation sections in a number of regions of the country having gentle contours but complex topography, especially in the Podzolic Zone.

On the collective farm Put Lenina (Pushkin district, Moscow region), there is a field of 46 hectares characterized by complex topography. On replowing in spring the soil was of such varying tilth that the tillage was very inconsistent. In places where the soil was tilled while wet, or where it had dried out, the tillage was crude regardless of the use of a number of supplementary methods. Such tillage cannot make it possible for the drill to work correctly and to distribute the corn seed evenly and properly. As a result, patches of water were produced. This was then responsible for thin and uneven stands of plants and for their spotty development, resulting in a low yield of silage in return for large expenditures on care, supplementary fertilization, and so forth.

Differential agricultural practices would have been some help in the tillage of separate portions of the field; but this did not satisfy the "requirements" of the mechanization specialists.

We have seen similar occurrences on a number of collective farms in the Chekhov district of Moscow region. On the higher parts of a single field wheat winters well, but in the depressions it becomes drowned.

"Often both sandy and clay soils, as well as peat-bog chernozems, are found in the fields," writes agronomist G. N. Varich from Bryansk region, "and for this reason some parts should be sown with early spring crops because of the excessive moisture. At some places in the land, meadow, bushes and swamp are wedged in." (Zemledelie, 1957, No. 2.)

On one continuous section of the Voroshilov collective farm (Chekhov district) we estimated the oats crop to be about 40 centners per hectare in the field, or about 36 centners per hectare in the warehouse. This crop was achieved by using ordinary agricultural practices, but when the fields were in more or less uniform condition.

In the overwhelming majority of cases, small harvests of grains and other crops may be explained by the failure to observe the elementary requirements of good agricultural practices. At the Machine and Tractor Station facilities are supposed to be worked out for the detailed, quantitative evaluation of the land to be tilled on every collective farm as well as instructions for the differential agricultural practices for each tract based on its characteristics. We must eliminate this oversimplification in the methods and systems of tilling the soil without regard to the features of each part of the area or to changes in these at different times. In many cases the mechanical tillage of the soil should be carried out by following contours which are more gentle but which include soils which are uniform in physical and textural composition replacing bigger tractors by smaller ones in the operation.

Large-scale studies of arable land resources on collective and state farms to provide a foundation for differential agricultural practices, and primarily for differential methods for mechanical tillage of the soil, should be carried out, according to the MTS, by agronomists and specialists in land use and mechanization and by agronomists of the collective farm with soil scientists participating. The primary unit for the calculation of arable land should be the crop rotation field as it is now made up.

The information provided by modern soil surveys and maps does not provide an answer to the extremely important questions of the production characteristics of arable land resources. They are generally slanted toward the rational application of fertilizer. They do not give enough complete agronomic information to provide a basis for determining the differential measures suitable for the peculiarities of individual fields and, within the fields, of individual terrain features. Special importance should be ascribed to the detailed characterization of intermediate and microrelief, to the predetermination of differences in hydrothermal conditions, and to the redistribution of moisture and heat. The characterization of soils and relief should be supplemented by certain symbols which are of great importance for production conditions but which are not reflected in the information obtained from soil surveys. Among these we include the geographical situation of fields, position of the snow cover, stagnant water from snow-melt and rainfall, contours of optimum soil tilth by dates, and condition of the fields with respect to cultivation. Established patterns of content and methods of soil surveys restrict their potential use for large-scale production.

The most important agronomic characterizations of the soils may be supplemented by considering the condition of plants cultivated on them (growth, development, comparative productivity) on individual land contours within the field and for the tilled area as a whole. Such investigations are already known to agronomists but are not used in soil surveys. For virgin lands the geobotanical method of evaluation according to natural vegetation is used. We consider that the use of such soil characterizations in surveys of long-tilled lands for agronomic purposes would fill a very important gap in agronomic soil science. Replacement of agronomic soil investigations by the so-called agro-economic surveys (in the form in which they are now used in land use planning) would lead to a different kind of synthetic substitute, inadequate for the correct organization of an area and for the determination of differential agricultural practices.

In this article we cannot dwell in any more detail in questions dealing with the contents and methods of soil investigations in land use planning, or on the requirements of agricultural practices for area classification. These questions require special consideration, and we prefer to return to them. The integrated organization of fields must not be considered as an accomplished fact. Much can and must be done to improve the fields of collective and state farms without breaking them up. We must, however, clarify the basic shortcomings of land use planning set forth above if we are to direct this planning toward the improvement of those conditions which, to an extreme degree, have limited progress in agriculture.

The need for the improvement in land use planning which is incidental to the new economic demands on agriculture has now become especially acute. In this connection advance plans for the development of collective farms are being reconsidered. Moreover, great significance must be given to reconsideration of the productive organization by area of crop rotation sections and fields and their improvement by measures of the land use planning type. In large crop rotation sections composed of several soil profiles, the differences among which cannot be spanned by available agrotechnical means, it is permissible to divide up the large section organizing independent crop rotations on the uniform soils. In order to create sufficiently uniform fields or even half-sized fields of a single type of crop rotation, it is permissible to locate them on separate sections to improve the organization of the care of such fields. Use of crop rotation sections (wedges) may be introduced to tracts similar in soil type but at different locations for short rotations, or by alternating crops on these tracts only for a time. Other solutions to this question may be found. In any case, agronomic supervision must be intensified in regions where crop rotations are distributed on soils with varying contours. They require much more attention with respect to strict differentiation of farming practices than is the case in regions with more or less uniform soils.

On some fields located on collective farms of the non-chernozem zone it is possible to observe the failure of winter crops, especially of winter wheat. On the same fields there may be a completely satisfactory crop of oats or potatoes. In other cases there may be better crops of winter sowings and it may be possible to plant one winter crop right after another. In some cases it is expedient to occupy part of the field with winter crops (where they pass the winter well) and the remainder with spring crops (in spots where the winter crops fail). Such a deviation from the cycle should not be considered as unacceptable. The correct solution of these questions is without doubt related to a systematic study of the special production characteristics of land resources.

The study at the station of the special agricultural production features of arable land resources on collective and state farms is the primary problem of land use specialists and agronomists of the Machine and Tractor Station, of collective farms, and of state farms. Direction of this work should be assigned to the Soil Management and Conservation Service. On this basis the plans should be drawn up for the allocation of crops in individual regions and within farms.

AGRONOMY SEMINAR
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Methods

SOILS OF THE EASTERN EUROPEAN TUNDRAS[1]

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THREE soil subzones in various natural conditions may be distinguished in the tundra of the far north of the European part of the USSR: arctic, northern, and southern. The boundaries of these subzones coincide generally with the boundaries of the botanical subzones.

Three Soil Subzones

I. Arctic Subzone of Tundra. The arctic tundra is not widely distributed in the European part of the USSR. It includes the southern part of Novaya Zemlya, Vaigach Island, and the shores of the Karsk sea at the Yugorsky Shar strait. This subzone is characterized by severe climatic conditions—very low temperatures and exceptionally high winds. There, on the dry areas between rivers with clay loams, are distributed polygonal, spotty and similar tundras with extremely scanty vegetation. In stony and sandy gravelly soils, extremely hard polygons are found in which low-growing shrubs occur: members of the genus Dryas and the plant *kovrik kasionen.* These form the dryad and kovrik tundras. In the same locations areas of lichen (reindeer moss) tundras are found, while in waterlogged locations, moss tundras develop.

Evidently, the initial stages of the soil-forming processes in the arctic subzone of the tundra are directly related to the severe climate. To a considerable degree this climate suppresses biochemical processes (gleying and humification) and causes intensified development of the physical processes—freezing, and other physical weathering, and so forth. Here the crypto-gleyed structured soils are formed in combination with the superficially gleyed polygonal and mottled soils. Crypto-gleyed solonchaks develop mostly near the seashore. There are no chemical data on these soils and they are the least studied of all.

II. Northern Subzone of Tundra. The northern tundra is distributed on the Malozemel'skaya and Bol'shezemel'skaya tundras. Here there is wide development of the moss-lichen tundras with spotty and small-mound microrelief. In addition to mosses and lichens, grasses are also found (sedges and cottongrass) as well as several low shrubs.

In the northern subzone of the tundra as a result of waterlogging of the soil and the presence of permafrost near the surface, leaching of the soils does not take place; anaerobic bacterial processes prevail and the reduction of oxides is intensified. All this leads to gleying and to the formation of a gleyed thixotropic horizon in the soil profile. Presence of spotty vegetative cover and small mounds on the surface determines the micro-complexity in this subzone. The surface-gleyed soils of the tundra alternate at short distances (0.5 to 1.5 m.) with the residual-gleyed soils of the tundra (in "spots"). These soils usually develop on fine-textured and intermediate parent material. Tundra illuvial-humic soils are formed on sandy and sandy loam parent materials. There is almost no spottiness on coarse-textured soils. When spots appear, large basins are formed like a deflated bubble. Peaty or peat-like gleyed soils develop on the wettest parts of the tundra.

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[1] This article is based on the author's personal observations of the Kanino-Timanskaya, Malozemel'skaya, and Bol'shezemel'skaya tundras from 1952 to 1955. The greater part of the data, especially that concerning the analytical treatment of the samples of tundra soils, could not be given here because of space limitations. The tables give the analyses of the most typical tundra soils. However, the characterization of the dynamics of tundra soil formation is based on all the factual material available to us. Data from the literature were also used.

Soil sections on clay loams and clay parent materials have the following structure: The shrub-moss litter (2 to 7 cm. thick) is underlain by a thin (2 to 6 cm.) discontinuous coarsely humic accumulative horizon of a dark-gray color. Under it is located a well-developed (18 to 20 cm.) gleyed horizon of a brownish-gray color having thixotropic properties.[2] Below this is watersoaked parent material. Soil sections made on the spots (medallions), except for the absence of litter and to some extent of the accumulative horizon, have a similar structure. It is interesting to note that in soil sections from the spots, vertical mixing of the components can be seen; the greatest axis of the detritus and rubble is directed perpendicularly to the surface of the spot; the surface is more clayey than the lower levels.

In clay loams the permafrost is at a depth of 1.0 to 1.3 m. in July and August. The horizons in the permafrost zone are a blue-gray, evidently depending on their original coloration, for the weathering processes here are strongly inhibited.

On sandy and sandy loam parent material, the soil profile differs from that described above: the thinner (0–2 cm.) lichen-moss litter is underlain by an interrupted humic accumulative layer with blue-gray spots. Beneath this is a well-developed illuvial-humic horizon of dark-gray color with light-brown and dark spots and traces of gleying. The permafrost lies at 1.2 to 1.5 m.

On watersoaked areas the thickness of the top peat layer reaches 10 to 20 cm., showing the present peat accumulation in the tundra. Under the peat lies a gleyed humic-accumulative horizon. In these soils the permafrost lies at 0.5 to 0.6 m.

An interesting peculiarity of the tundra soils is the poorly developed soil horizons, expressed morphologically, especially in the clay loams. This is caused by the fact that the entire soil profile has a dirty gray tinge which conceals the faint color transitions. This is distinguished from tundra soils on coarse-textured materials by the latters' clearly developed illuvial-humic horizon which is dark-brown in color with traces of gleying. In the transition to the podzolic type it becomes paler, the characteristics of gleying are not as pronounced, and a podzolic horizon is formed in its place.

The results of particle-size analysis of the tundra soils show the removal from the upper soil horizons of clay fractions (<0.002 mm.) and an increase in them in the layer above the permafrost. M. I. Sumgin (8) explained a similar phenomenon by the eluviation of the clay particles from the upper horizons down to the barrier of the frozen layer during the warm periods of the year and by the grinding action of the soil particles on freezing.

An important influence on the physical condition of tundra soils is their high moisture content, extending to the lower limit of viscosity. However, the high soil moisture in the natural state does not always cause quicksand phenomena. Only after it has been acted on mechanically does it acquire quicksand properties. This phenomenon has been observed under natural conditions by many investigators of the north (2, 5, 6, 7 and others). N. Ya. Denisov and P. A. Rebinder (3) state that clays under natural conditions at a moisture content above the lower limit of plasticity and even above the lower limit of viscosity are in a solid state. Mechanical action makes them plastic or viscous without changing their moisture content. They explain this phenomenon by the formation on the surface of the clay particles of colloidal films of silicic acid, which cement together particles of different sizes. The clays then form thixotropic structures in water with participation of the nascent colloidal films.

In Tables 1 and 2 are shown chemical and gross analyses of tundra soils; consideration of the tables leads to the following conclusions:

1. In soils of the northern tundra there is either an insignificant amount of leaching or it is totally absent. This is shown by the increased amount of silica and the decrease in residual oxides at the bottom of the profile. If, in some sections, a decrease in silica and an increase in sesquioxides is observed at the bottom of the profile, this is related to a redistribution of the small-particle fractions of the soil in the active layer during the warm period, or with residual

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[2] Under mechanical action this horizon goes over into a quicksand-like consistency.

TABLE 1

Combined table of chemical analyses of the soils of the northern tundra.

Description of section	Horizons	Depth in cm.	On absolutely dry soil											Easily accessible iron, mg. per 100 g. soil (Kirsanov's method)
			Total humus (Turin's method) %	Water-soluble humus, %	pH		Hydrolytic acidity	S (Kappen's method)	V	H	Al	Ca	Mg	
					Water	Salt				In me. (Sokolov's method)		Adsorbed in me.		
Section 2. Northwest part of Bol'schezemele'skaya tundra under moss-lichen vegetation; clay loam, surface-gleyed tundra soil	A_1d	4–8	2.1	0.0504	4.38	3.30	19.69	8.20	73.53	0.31	3.05	12.64	2.29	210
	d	10–20	1.31	0.0121	5.35	4.08	3.06	6.20	76.95	none	1.50	3.50	0.75	80
	Bh	60–80	0.26	0.0106	6.60	5.33	0.87	15.20	94.58	0.02	none	10.28	3.99	30
Section 1. On a spot (medallion); clay loam, residual-gley tundra soil	d	5–10	1.52	0.0239	4.38	3.27	17.34	3.9	34.69	0.46	7.75	2.71	0.93	199
	Bd	20–40	0.62	0.0105	5.61	4.30	2.62	13.9	84.14	0.04	0.32	8.28	2.19	22
Section 3. Under moss-lichen vegetation; sandy, illuvial-humic tundra soil	A_1	2–6	1.79	0.0176	5.13	4.01	4.55	1.60	26.01	none	0.80	1.6	0.28	76
	Bh	20–30	1.09	0.0119	5.85	4.21	4.72	2.43	33.98	none	0.86	1.6	0.83	100
	C	70–80	0.15	0.0111	5.76	4.35	1.57	1.70	51.98	none	0.44	1.5	0.50	12
Section 4. Under shrub-moss bog vegetation; peaty-gleyed tundra soil	A_1	20–30	4.02	0.0137	4.45	3.90	6.82	2.65	27.60	0.02	1.88	1.40	0.40	150
	Cd	40–50	0.18	0.0111	6.00	4.64	0.78	3.10	79.89	none	0.04	0.395	0.56	70

characteristics preserved from the time of the development of thick podzols here during the climatic optimum (a relict).

2. The reaction of tundra soils is acid or slightly acid. This is explained by the large content of fulvic acids in the humus. Water-soluble humus is observed in almost all horizons of the soil. Its maximum is associated with the accumulative humic layer. The decrease in water-soluble humus at the bottom of the profile is closely associated here with the decrease in total humus.

3. Hydrolytic acidity is high along the entire profile and increases gradually in the upper horizons, reaching a maximum in A_1 or A_1d. Among the adsorbed cations, there is considerably more aluminum than hydrogen.

4. The total adsorbed cations gradually becomes larger going down the profile, sometimes, however, they are uniform through all the horizons. Among the adsorbed cations there is more calcium than magnesium. The degree of cation saturation is high along the entire profile, amounting to 30 to 70%. This is especially distinctive as compared with the podzolic soils of the northern taiga subzone, where the cation saturation varies between 10 and 30%.

5. Tundra soils are characterized by a considerable content of mobile iron, which reaches a maximum in the upper horizons.

TABLE 2

Summary table of chemical analyses of northern tundra soils.

Section No.	Depth, cm.	Content in percent of mineral substance								
		SiO_2	TiO_2	Al_2O_3	Fe O_3	MnO	CaO	MgO	K_2O	Na_2O
2	4–8	76.62	0.76	12.04	3.62	0.09	1.41	1.12	2.45	1.28
	10–20	77.65	0.68	11.63	3.44	0.08	1.28	1.07	2.09	1.50
	60–80	78.95	0.84	9.91	3.34	0.08	2.06	0.39	2.06	1.62
1	5–10	78.62	0.79	11.51	2.45	0.03	0.89	1.28	1.8	1.4
	20–40	77.22	0.66	12.05	3.82	0.07	1.41	1.1	2.21	1.59
3	2–6	88.5	0.37	6.49	0.16	0.02	0.91	0.23	1.58	0.95
	20–30	88.9	0.28	5.79	0.83	0.02	0.80	0.36	1.43	0.8
	70–80	88.74	0.25	5.91	1.02	0.01	0.73	0.17	1.63	0.66
4	20–30	83.01	0.38	8.06	1.67	0.02	0.88	0.53	1.87	1.2
	40–50	83.07	0.57	9.63	1.16	0.03	1.09	0.51	2.20	1.52

III. Southern Subzone of Tundra. The southern boundary of this zone coincides with the northern tree line. The zone occupies enormous areas on the Kol'skii, Kanin and Timan peninsulas and on the Malozemel'skaya and Bol' shezemel'skaya tundras. The interfluves of this subzone are covered with thickets of tundra shrubs: willow and dwarf birch with shrub-moss or shrub-lichen soil cover.

As in the northern tundra, "spotty" plant cover has developed here too, predominantly on fine-textured soils.

In this subzone the gleying and leaching processes predominate over the frost damage (heaving), resulting in the formation of a complex of

TABLE 3

Summary table of chemical analyses of southern tundra soils.

Description of section	Horizons	Depth in cm.	On absolutely dry soil											Easily accessible iron, mg. per 100 g. soil (Kirsanov's method)
			Total humus (Turin's method) %	Water-soluble humus, %	pH		Hydrolytic acidity	S (Kappen's method)	U	H	Al	Ca	Mg	
					Water	Salt				In me. (Sokolov's method)		Adsorbed in me.		
Section 5. Under shrub-moss-lichen vegetation; soil: surface-gleyed clay loam with signs of podzolization	A_1	3–10	4.25	0.0259	4.55	3.70	9.53	3.70	27.96	0.06	1.74	1.30	0.79	170
	g	10–20	0.23	0.0072	5.18	4.08	2.10	5.80	74.07	0.02	0.58	3.20	0.57	80
	Bh	60–70	1.08	0.0091	5.63	4.64	1.48	20.0	93.11	0.02	0.02	11.39	6.61	30
Section 6. Under shrub-lichen vegetation; soil: podzolized, sandy illuvial-humic tundra	A_1A_2	3–10	0.34	0.0085	5.83	4.35	0.70	1.90	73.07	none	0.06	1.40	0.46	40
	Bh	10–25	1.32	0.0095	5.78	4.55	1.40	1.40	50.0	none	0.08	1.40	0.17	35
	C	50–60	0.16	0.0080	5.93	4.42	0.70	2.80	80.0	none	0.20	1.20	0.79	15
Section 7. Under crooked birch (*Betula tortuosa*); soil: illuvial-humic dwarf sandy podzol	A_1A_2	5–10	0.74	—	6.5	4.5	1.84	1.05	37	—	—	—	—	—
	Bh	10–15	2.88	—	6.2	4.5	3.48	0.1	30	—	—	—	—	—
	C	30–40	0.26	—	6.3	4.5	2.78	0.1	34	—	—	—	—	—

TABLE 4

Summary table of gross analyses of southern tundra soils.

Section No.	Depth, cm.	Content in percent of mineral substance								
		SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	CaO	MgO	K_2O	Na_2O
5	3–10	76.94	0.73	13.05	2.20	0.03	1.39	1.05	2.26	1.67
	10–20	77.47	0.85	12.27	2.49	0.06	1.51	1.15	2.20	2.04
	60–70	71.15	0.87	14.94	6.08	0.06	1.39	2.02	2.55	1.32
6	3–10	92.58	0.33	3.33	0.67	0.01	0.95	0.18	1.25	0.55
	10–25	87.85	0.28	7.07	1.24	0.03	1.51	0.23	1.45	0.91
	50–60	89.51	0.38	5.20	1.62	0.02	0.76	0.19	1.51	0.84
7	5–10	93.84	—	2.91	0.78	0.06	0.31	0.9	—	—
	10–15	87.06	—	4.94	1.78	0.06	0.55	0.79	—	—
	30–40	90.72	—	3.74	2.73	0.08	0.55	1.06	—	—

tundra surfaced-gleyed and residual-gleyed podzolized soils on fine-textured soils, and of illuvial-humic podzolized soils of coarse texture. The tundra illuvial-humic dwarf podzols are encountered along the river valleys at the southernmost limit of this subzone and are, so to speak, a connecting link with soils of the podzolic type. In the southern tundra bogs occupy an enormous area in comparison with the remaining portion of the zone. This is also characteristic of the more southerly landscapes. Consequently, isolated traits of the composite northern taiga subzone appear in the southern tundra.

A distinctive characteristic of southern tundra soils is the appearance of a well-developed podzolic horizon beneath the litter. For the rest their soil profile is similar to those of the northern tundra soils.

In Tables 3 and 4 are shown the chemical and gross analyses of soils in the southern subzone of the tundra. The analytical data cited in these tables show a definite, regular geographical pattern reflecting increasing podzolization of the soil as one moves from north to south. The southern tundra soils show clear signs of podzolization which are quite pronounced both morphologically and chemically. An accumulation of humic substances and sesquioxides consisting of significant amounts of alumina is taking place in the illuvial soil horizon. This shows the high mobility of organic matter and alumina in the southern tundra soils. The organic matter, which, together with the alumina is drawn downwards into the profile, precipitates from solution when the acidity is decreased, giving the soil profile a gray-brown hue and causing an increase in hydrolytic acidity in the lower soil horizons. The degree of cation saturation in these soils is considerably lower than in the tundra soils of the northern subzone.

The soils being examined here, as distinguished from podzolic soils, are characterized by a dwarf profile, greater mobility of alumina than of iron, and considerable surface gleying. A gley horizon with thixotropic properties is formed in the clay loams of these soils.

Generalizing the work of a majority of investigators of the tundra zone, especially of recent work (4, 5, 6, 7), and on the basis of personal observation, we may define tundra soil formation as being of an independent soil type. The essence of the tundra soil-formation type develops from the mutual interaction of two opposing processes: a) the biochemical processes of superficial gleying and gradual leaching downward of the products of soil formation as a result of the infiltration of atmospheric precipitation and b) the upward displacement of the products of soil formation as a result of freezing.

These processes occur at different times. While the biochemical processes of superficial gleying and the eventual migration of its products develop during the warm period of the year, the freezing out and related upward displacement of the products of soil formation (and sometimes of skeletal particles) take place in the fall and winter. The latter fact has been emphasized many times by investigators of the tundra, particularly by I. A. Tyutyunov (9).

Periodic displacement of the soil solution and of the soil mass is characteristic of the tundra type of soil formation. One of the factors is the perennial freezing, which acts as a water barrier and prevents drainage of the products of soil formation from the active layer.

The processes of decomposition and synthesis of organic and organo-mineral matter proceed under conditions of high moisture and low temperatures. Most of the microbiologists who have studied the tundra soils have come to the conclusion that anaerobic bacteria and fungi are widely developed in these soils. A. V. Baranovskaya, in her work on the Vorkuta tundras (1), emphasized that a characteristic feature of the organic matter in tundra soils is the unusually low humic acids content and high content of bitumen and fulvic acids.

The migration of the products of soil formation may be conditionally (in the absence of adequate data) described as follows: Relatively large amounts of iron oxides (100 to 150 milligrams per 100 grams of soil) form from anaerobiosis in the tundra soils; an especially large quantity accumulates in the litter and in the humus horizon. Organic acids, mostly fulvic acids, unite with the mobile forms of iron to form easily soluble and reactive compounds. Acting on the aluminum-silicate complex of the soil, they partially decompose it, freeing mobile silicic acid, aluminum oxides and other elements. Organo-mineral compounds and compounds of these elements are formed. They become hydrated and lose their mobility, remaining stored in the humus accumulation and gley horizons to which they impart thixotropic properties. Only a part of them, predominantly lower oxides and free fulvic acids, penetrate with the descending water flow into the horizon below the gleyed layer. There they are oxidized and lose their mobility. Drainage of these compounds from the seasonal layer is prevented by the presence of the permafrost. However, farther toward the south in the southern tundra, where the frost is not solid, a portion of the substances do flow off with the ground water. This explains some podzolization of the soil. With autumn and winter flow, a part of the mobile substances and skeletal particles are raised to the upper layers where they accumulate. That is why a maximum of the mobile iron and fulvic acids is observed in the upper soil horizons.

Conclusion

The tundra soils were formed as a result of a unique tundra soil-forming process, as shown in the biochemical process of surface gleying and in the periodic displacement of the products of soil formation along the soil profile, owing to infiltration of water during the warm period of the year and freezing out in the fall and winter. The weak or hidden podzolization of the tundra soils noted by a number of authors is an extremely rare phenomenon; it is a relict of ancient soil-forming processes at the period of the climatic optimum.

In the tundra zone corresponding to the vegetational subzones (arctic, northern and southern), three subtypes of tundra soils are distinguished:

1. An arctic soil-forming process which is close to the initial stages of soil development. Types: a) structural soils with concealed gleying (developed on unclassified parent material); b) polygonal and spotty soils (developed on classified parent material); c) solonchak soils with concealed gleying (developed on salinized parent material in seashore regions).

2. Typical tundra soils. Types: a) complex surface-gleyed and residual-gleyed soils (on fine-textured material); b) illuvial-humic soils (on coarse-textured material).

3. Southern tundra soils with traces of podzolization. Types: a) surface-gleyed podolized (on fine-textured parent material); b) illuvial-humic podzolized soils and dwarf podzols (on coarse-textured material).

Soils may be distinguished by their degree of surface gleying, illuvial-humic processes, leaching, freezing out, and so forth.

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METHODS OF DIAGNOSING THE NITROGEN REQUIREMENT OF PLANTS

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CONSIDERING the great need of plants for nitrogen and the rapid leaching from the soil of its compounds which are available to plants, supervision must be carefully exercised on the reserves of this element for cultivated plants in order to establish the timeliness of the use of nitrogen fertilizers. For this purpose the so-called "leaf diagnosis" method is used widely and successfully (13, 14, 15, 18).

Unquestionably, when deciding whether or not to apply fertilizers, consideration must be given not only to the properties of the soils, but also to the nutrient intake and content of plants in one or another stage of their development. The latter is especially important in relation to nitrogen.

One of the principal tasks involved in refining the methods of diagnosis by plant analysis is to clarify the relationship between the chemical composition of plants and the internal and external factors of their growth. It has been established in particular that the fractional application of nitrogen during the growing period (especially with adequate moisture) increases the effectiveness of nitrogen fertilizer (3, 11, 12).

It is known that nitrogen is present in plants in different forms. Of these, the nitrate form is the most direct indication of the supply of nitrogen for the plant from the soil.

For the determination of nitrogen by rapid methods, two techniques are ordinarily used. The first, which is the more widespread and dependable, consists in the production of a blue color in plant sections as a result of the reaction of diphenylamine with nitrates. It has been recommended at different times by a number of authors: L. N. Hoffer (13), E. Moeller, Arnold and Feiching (16), H. Niklas and F. Grandel (17), G. S. Davtyan (1, 2) and others. The presence of nitrates (total nitrate) by the second technique is shown by a pink color with sulfanilic acid and naphthylamine (Griess reaction using dry reagent according to Bray). (K. P. Magnitskii (4); K. Schutt (19)). We have continued to use the diphenylamine method with plant sections, especially with such plants as cereals and grains from which the juice could not be extracted. In this case a coarsely shaved section or piece of the stem, leaf, its petiole, root or other organ of the plant to be examined is placed on a glass slide. Then the section is covered with a drop of diphenylamine solution, prepared by dissolving 0.1 g. of diphenylamine in 10 ml. of sulfuric acid, specific gravity 1.84. The degree of coloration is estimated by a seven-step scale which we made up (see Table 1). As a rule, the nitrate content of plants agrees well with the extent of the soil supply of nitrogen.

We have carried out several thousand determinations of nitrates in plants in greenhouse and field experiments carried out under various soil and climatic conditions. The following plants were analyzed: cereals—winter rye, winter wheat, spring wheat, oats, barley, corn, millet, timothy, foxtail, awnless and straight bromegrass, meadow fescue, orchardgrass, Kentucky bluegrass; legumes—red clover, hybrid alfalfa, vetch, and hop-like alfalfa; tubers and edible-root plants—potatoes and sugar and fodder beets; other plants—cabbage, white mustard, cleavers, iris, bottlegrass, orache, and others. In the present article we will present only a part of these data. Table 2 summarizes the results of the analysis of spring wheat from greenhouse (1944–1948) and field experiments in Kalinigrad region in 1950.

The micromethod we use is sufficient to give a good reflection of the extent of nitrogen supply of the plants, especially in greenhouse experiments. Good results were also obtained in the field experiments using diphenylamine: on plots without nitrogen fertilizer nitrates were not detected in 83.8% of the cases, while in plants on plots with nitrogen fertilizer, on the other hand, nitrates were not detected in only 8% of the cases, and in 92% they were found in varying quantities.

The extent to which nitrogen is supplied to winter cereals may also be diagnosed by their nitrate content. This is shown by the results of

TABLE 1

Scale for the determination of nitrates in plants.

Scale Step	Color	Plant requirement for nitrogen fertilizer
6	Section and solution quickly turn an intense blue-black. Color persists.	None required; excess of nitrates.
5	Section and solution immediately turn dark blue. Color persists for some time.	Not required.
4	Section and solution turn blue. Color does not appear immediately.	Slight requirement.
3	Same. Color light-blue, disappears in 2 to 3 minutes.	Moderate requirement.
2	Mainly the vascular bundles which turn light-blue. Color disappears quickly.	Required.
1	Traces of evanescent blue color.	Strong requirement.
0	No blue color. Tissues begin to turn pink and blacken as a result of charring from H_2SO_4 reagent.	Intense requirement.

TABLE 2

Nitrates in spring wheat.

Experiments	Year	Treatments	Incidence of scale ratings								Same, as percent						
			0	1	2	3	4	5	6	Total	0	1	2	3	4	5	6
Greenhouse	1944–1948	Without nitrogen	42	—	—	—	—	—	—	42	100	—	—	—	—	—	—
		With nitrogen	10	5	5	15	16	19	69	139	7.2	3.6	3.6	10.7	11.5	13.7	49.7
Field	1950	Without nitrogen	63	1	1	4	—	—	2	71	88.8	1.4	1.4	5.6	—	—	2.8
		With nitrogen	11	20	13	28	29	21	15	137	8.0	14.6	9.5	20.4	21.2	15.3	11.0

TABLE 3

Nitrates in winter wheat plants.

Experimental plant	Treatments	Incidence of scale ratings								Same, percent						
		0	1	2	3	4	5	6	Total	0	1	2	3	4	5	6
Winter wheat	Without nitrogen	5	1	—	—	—	—	—	6	83.4	16.6	—	—	—	—	—
	With nitrogen	3	1	—	2	1	8	4	19	15.8	5.2	—	10.5	5.2	42.2	21.1

the analysis of wheat at the dough stage (Table 3), which we carried out on the plants June 4 and 6, 1956; they are taken from the field experiments of M. M. Nichik, a scientific colleague in the D. N. Pryanishnikov Dolgoprudnaya Agrochemical Experiment Station (DAOS) of the Ya. V. Samoilov Scientific Research Institute for Fertilizers and Insectofungicides (NIUIF).

Good results were also given by the determination in potatoes, beets, corn, grasses and other plants of the nitrate content as influenced by the amounts of nitrogen fertilizers.

Thus, the diphenylamine method of determining nitrates in plant sections is sufficiently sensitive for diagnostic purposes.

In diagnosing the nitrogen requirement of plants according to the data from analysis of their nitrate content, it must be kept in mind that factors from the internal and external environment exert an influence on the presence of nitrates in the plant. The internal factors influencing the nitrogen metabolism of plants and consequently their nitrate content include primarily the special characteristics of the genus and species of the plants, the age of the plant as a whole and of its individual organs, and the associated rate of the plant's synthetic, growth and morphological processes. In full-grown plants which have passed into the reproductive stage of development and possess a considerable assimilative surface and a large quantity of accumulated carbohydrates, the nitrate content decreases; in the flowering stage it even disappears altogether. The more quickly the plant completes its ontogenetic cycle, the more quickly its nitrates disappear. The plants are arranged in the following increasing series according to the

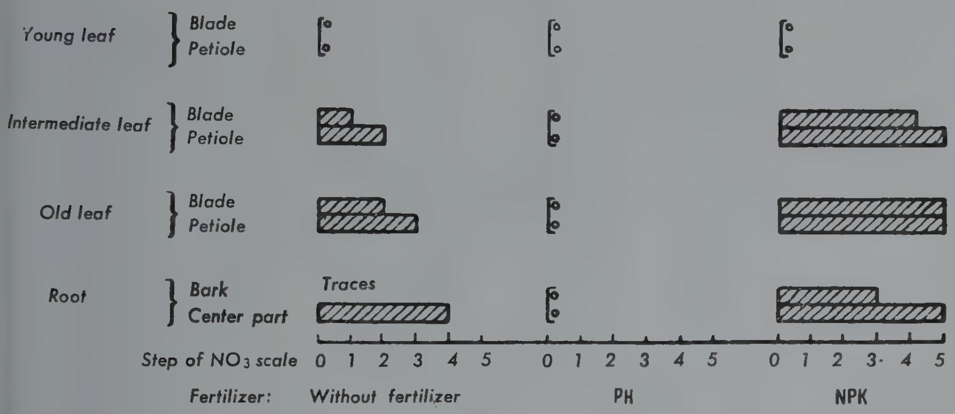

FIG. 1.—Nitrates in fodder beets from field experiments at Poltava Region Experimental Station, July 5, 1956.

duration of the period in spring during which nitrates are detectable in them: winter rye < winter wheat < spring cereals < potatoes < beets.

For the successful diagnosis of the supply of nitrogen to the plant, the choice of plant organs for analysis is important; the younger the green organ, the less nitrate in it; in meristematic tissues and growing points we never detected nitrates (Figs. 1 and 2); in these tissues nitrogen is in reduced form as ammonia, amino acids, proteins, and so forth. In this connection, for diagnostic purposes the lower, more mature, but still green parts of the plant should be used: stems, nodes, leaves (there are more nitrates in the sheaths and petioles of the leaves than in the blades).

The micromethod makes it possible to follow the rate of movement of nitrates in the plant organs after the application of fertilizer (Table 4).

From the data in Table 4, it is seen that after the application of nitrogen fertilizer, nitrates were detected very quickly (in the first few hours) in the lower parts of the plant. After 24 hours they had risen higher. The rate of their transfer is affected by the nitrogen content of the plant before the application of fertilizer: the more intense the hunger of the plant for nitrogen, the more rapidly the nitrates were converted in the lower organs and the later they were observed in the upper ones.

In addition to internal factors (species of plant, age, rate of growth, qualities of the organs analyzed, character of the metabolism, and so forth) there are a number of external factors which also exert an influence on the presence of nitrates in the plant. For example, the supply to the plant of other elements of nutrition (especially P and K) exerts a strong effect on the use and conversion of nitrates in the plant. In a number of cases perceptible quantities of nitrates were observed in unfertilized control plants, while there were no nitrates in plants on plots with P-K fertilizers. In these cases the phosphorus and potassium fertilizers had made possible a more rapid consumption of the nitrates at an earlier period. This may be seen, for example, in Fig. 1, which shows the distribution of nitrates by organs in a sugar beet taken in field experiments by our senior scientific colleague I. D. Rogoz, section chief at the Poltava Regional Experimental Station (our analysis was performed July 5, 1956).

Methods of soil tillage, improving root growth, and increasing the vitality of the plants also affect the plants' nitrate content. Thus, in field experiments started in 1950 at the Kaliningrad State Selection Station, we made analyses in the spring of 1951 for the presence of nitrates in winter rye from plots with sowings at two different times, one optimal and the other the latest possible time of sowing, in which the plants were sharply differentiated in color, foliation, bushiness and rate of growth. The results of the analysis showed that the rye sown at the optimal time was richer in nitrates than the rye from the late sowing, even though all the plots had been uniformly manured and tilled. The plants of the optimal sowing had a more branching root system, remained stronger through the winter and then, in spring, were able more fully to use the soil nu-

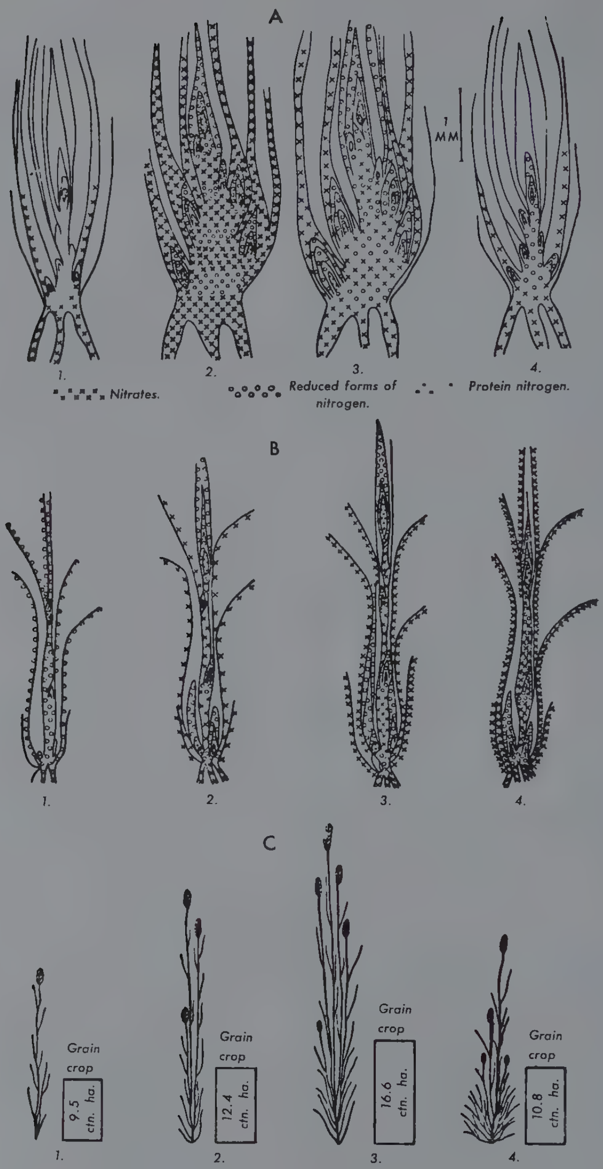

FIG. 2.—Spring wheat (Pobeda Collective Farm, Primorskiy District, Kaliningrad Region, 1951).

A.—Three-or-four-leaf phase (15 diameters enlargement). Fertilizers: 1—no fertilizer; 2—all N before sowing; 3—½ N before sowing; 4—no nitrogen. B.—Five-or-six-leaf phase (2 diameters enlargement). Fertilizers: 1—no fertilizer; 2—all N before sowing; 3—½ N before sowing, ½ N as early supplement (3-or-4-leaf phase); 4—all N as supplement (½ N in 3-or-4-leaf phase, ½ N in 5-or-6-leaf phase). Symbols as in A. C.—The crop and its structure. Fertilizers: 1—no fertilizer; 2—all N before sowing; 3—½ N before sowing, ½ N in early (3-or-4-leaf) supplement; 4—all N in supplement (½ N in early 3-or-4-leaf phase, ½ N in 5-or-6-leaf phase).

trients, to grow and develop faster and, as a result, give a larger crop of grain. Thus, observation of the nitrate content of the plants revealed one of the causes of the favorable effect of the sowing time.

In order to make correct decisions on questions concerning the system of soil fertilization under one kind of a plant or another, particularly with nitrogen fertilizers, it is important to establish what kind of nitrogen nutrition is to be given to such plants at what period of their development, and what effect changes in nutrition will have on the size of the crop. In this way the desirable type of nitrogen nutrition of the plants is established. Limiting our consideration of the question to the nitrate conditions in plants as related to the crop size, we shall cite as an example the results of a field experiment, with the times of application of nitrogen under spring wheat, which was carried out by us in 1951 on the Pobeda collective farm, Primorskii district, Kaliningrad region, on a peaty, residual, weakly-podzolized, fine humus, a slightly cultivated medium clay loam underlain by a fine-textured clay loam. The soil acidity increased with depth from a pH (KCl) of 6.6 to 4.4. The soil was comparatively poor in phosphorus—15 mg. of P_2O_5 per 100 g. of soil—but rich in potassium—36 mg. of K_2O per 100 g. of soil.

In Figure 2, A and B represent the distribution of forms of nitrogen compounds in sagittal sections of young wheat plants (at the three-leaf and five-leaf stages) with four treatments: 1) without fertilizer; 2) with the entire quantity of nitrogen applied before sowing; 3) half the quantity of nitrogen applied before sowing, the other half early in the growing period—at the three-leaf stage; and 4) the entire quantity of nitrogen applied after sowing, that is, in two applications at two different times—half at the three-leaf and half at the five-leaf stage.

In Figure 2, A shows the distribution of the forms of nitrogen compounds in the young plant when fertilized before sowing. It can be seen that the non-fertilized plants (treatment 1) have a very small nitrogen content, obviously due to the small content of it in the soil and its quick conversion in the plant to the more complex forms of nitrogen compounds. On the other hand, in plants receiving the entire quantity of nitrogen before sowing (treatment 2) there was a considerable excess of nitrates. This is evidently to be explained by a more abundant supply of nitrates to the plants and by some inhibition of the conversion of nitrates into other forms of nitrogen due to the relative insufficiency of carbohydrates at this phase of development—the plants not yet fully leafed-out. In the plants in treatment 3, the ratio of nitrates to carbohydrates was more satisfactory so that nitrates were detected in average quantities, but the amount of amino acids and proteins in the growing points was the greatest of all the treatments of the experiment.

TABLE 4

Millet. Greenhouse experiments on sand culture (1954). Nitrates in plant sections (according to scale steps).

Date of analysis	June 22					June 23	
Time sample taken	Before fertilization			4 hours after fertilization		24 hours after fertilization	
Part of nitrogen applied before fertilization	1	½	1/10	½	1/10	½	1/10
Part of nitrogen applied after fertilization	0	0	0	½	9/10	½	9/10
Roots	6+	1	0	5	4	6	2
Stem, lower	6	4	0	5	1	6	3
" middle	6	4	0	6	0	6	1
" upper	5	—	0	—	0	—	—
Leaves, lower	—	1	0	4	0	5	0
" middle	4	1	0	4	0	5	0
" upper	2	0	0	3	0	4	0

In Figure 2, B shows wheat grown under the same treatments, but at a more advanced stage—with five or six leaves, at the stage of spike formation when the culm is being formed, a month after the first application and in the days following the second application in treatment 4. At this period, in treatment 2 of the experiment when all the fertilizer is applied before sowing, there were less nitrates in the wheat than in treatment 3 which at first was given a reduced quantity of nitrogen (½N) but then subsequently received a supplement of ½N a month later. Such a regime of nitrogen nutrition made possible the development of the culm in this treatment not only the main culm but also the secondary ones developed most successfully. An excess of nitrates was detected in the wheat of treatment 4, which had been deprived of nitrogen at an early period and which had received the entire quantity of nitrogen in a latter supplement. This caused the processes of nitrogen and carbohydrate nutrition, both of the sprouting and of the growing organs including the meristem, to follow a different course, bringing about a further delay in bushing out and relatively worse development of the spikes.

Different conditions of nitrogen nutrition affected the formation of structural elements important in the crop right down to the complete ripening of the grain (the number of spikes per plant, size and number of grains per spike, and the 1000-grain weight), thereby determining the eventual size of the harvest. In Figure 2, B shows a diagram of the structure of the crop and the final grain harvest; from this it may be seen that the same quantity of nitrogen fertilizer, depending on the time applied, may give a crop increase of 1.5 to 4 centners per hectare of grain, that is, of 13.7 to 74.7%. Consequently, for spring wheat grown in the peat-podzolic zone, the following types of nitrogen feeding can be recommended. In the first period of development, when a significant amount of assimilative surface has not yet been formed (in the period from sowing to the stage of one or two leaves), the quantity of nitrates in the plants should not be very high. In the next stage (three leaves, the beginning of tillering and stem formation) the amount of nitrogen should be increased and maintained at this level during the phase of culm and spike formation. Beginning with the stage of seed formation, nitrogen feeding should not be increased unless there are problems, such as increasing the protein content of the grain.

Supervising the nutrition of plants and the timely application of nitrogen and other fertilizers are important measures in increasing efficiency and raising productivity. Analysis of the plants, including quick and simple microchemical analysis of sections of the live plant, is one of the methods of doing this.

Conclusion

1. Determination of nitrates in plant sections by the use of diphenylamine gives a satisfactory answer to the question of whether the application of nitrogen fertilizer is needed.

2. The content of nitrates varies with the genus and species of plant, its age and rate of development as well as the age and properties of the organs analyzed. Since there are more nitrates in young plants, the more rapidly the plant finishes its ontogenetic cycle, the more rapidly nitrates disappear from its organs. Within the plant there are more nitrates in the mature organs in the lower parts of the plant than in the immature ones, while nitrates are lacking in the meristem of the growing point. For this reason diagnostic analysis should be carried out on the lower leaves (preferably the petioles) or on the lower parts of the stem (preferably the nodes).

3. In using the data from plant analysis, it is necessary to take into consideration not only the internal growth factors of the plant, but also external conditions. The peculiarities of the soil, the supply of nutrients including those from applied fertilizers, agricultural methods, meteorological conditions, and other external factors the conjunction of which make it possible for the plant to grow: all these increase the passage of nitrates from the soil into the plant. On the other hand, late sowing, applying fertilizers containing only potash and phosphate, and other methods decrease the nitrate content of plants.

4. A combination of plant analysis and study of the formation of structural elements important in the crop up to the time of harvesting make possible the establishment of the most efficient method of applying nitrogen fertilizers for spring plants and assuring the production of a good grain harvest.

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EXPERIENCE IN USING 1:100,000 TOPOGRAPHIC MAPS FOR COMPILING 1:1,000,000 SOIL MAPS

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COMPILERS of medium and small-scale special maps of natural conditions find it difficult to use large-scale maps, especially soil and botanical maps, because of their lack of uniformity and because they usually do not cover the entire area of interest to them.

These circumstances often make it necessary to pursue supplementary investigations and to use other general geographic and special surveys of the area including topographic maps, which at present are of high quality being based on aerial photographs. The 1:100,000 topographic maps are especially important because they can be used in compiling maps for any area within the borders of our country.

In the present article we describe our experience in compiling a soil map of Altai krai on a scale of 1:1,000,000[1] using 1:100,000 topographic maps (1939–1946). The methods of using topographic maps in similar work is considered, and the advisability of such use is determined by an analysis of the accuracy and reliability of the results obtained.

The compilation was based on large-scale departmental materials (chiefly soil photographs from the Altai Land Planning Administration), materials from route investigations by the Special Composite Expedition, and sheets from the 1:1,000,000 State Soil Map of the USSR published in 1949.

In comparison with the latter, our map is not only corrected according to data from the latest investigations, but it is considerably more detailed. We tried to reveal in the contours the content of a larger part of the extra-scale map symbols used on the State Soil Map, the number of details of which has been decreased as against the potentialities of this scale, since the accepted qualification for the separation of soil contours (0.5–1 cm.^{2}) is itself too great, with the result that it is not strictly observed. The large-scale soil maps used in the compilation reveal only isolated tracts of the area to be mapped. They make it possible to compile a map of the required scale for these tracts and, with data gathered in the field, help to study the regular distribution patterns of the soil cover. The information obtained should be allocated on the area not included on the large-scale maps. Thus we obtain a kind of analogy with the "key" type method of investigation: we are confronted with the task of geographic extrapolation of data from the key tracts (tracts provided by the large-scale soil data) onto a wider area. This task is accomplished by the use of topographic maps. Here, the "key" method is used to clarify the details of the arrangement of soil cover and its intrazonal characteristics, while the general patterns touching on the zonal and subzonal types of soils are determined on the basis of other data—the State Soil Map and field data.

Indicators for the intrazonal types of soils (usually related to changes in the relief, moisture, and plant cover) are almost always found in the representation of soil-plant cover on the topographic map. In order to find such indicators we made a comparison of the topographic maps with the large-scale soil maps making it possible to establish, on the basis of a study of the patterns of distribution of the different soil types, those peculiarities which are related to changes in the soil cover. Such a comparison was carried out on key tracts shown on the large-scale soil maps and distributed in various soil zones, subzones and natural regions of the territory.

The work included a search for the indicators of different types of soils for each natural region—a unique "soil delineation" of the topographic map where for every cartographic symbol of the topographic map, or for combinations of them, an appropriate type of soil is found for a definite natural region. The success of this work depends on how well the general geographic pattern of soil cover distribution in the area to be mapped has been studied. We will clarify this by citing as examples two tracts, showing how the "delineation" was carried out and what results were obtained. The first tract is located in the subzone of the southern chernozems in a region of ancient terraces on the northwest part of the Pre-Ob plateau. From the large-scale soil maps the region appears to be characterized by great complexity of soil contours, most of which can be expressed within the scale of the map. A comparison of the soil map with the topographic map shows that the contours of bogs, solonetzes and solonchaks on the topographic maps correspond to the contours of the meadow-bog solonchak soils, solonetzes, and solonchaks on the soil maps. Forest-covered circular depressions and slanting ravines on the slopes of the plateau have a cover of dark-gray solodized soils and solods. Virgin tracts between small stands of trees along ravines on slopes of the plateau, designated by the symbol "steppes with solonchaks," correspond to solonetzes, while tracts on the bottoms of ravines of old waterways, designated as "meadow," are meadow-chernozem solonetz soils. Areas under cultivation, including separate cultivated tracts on the lower terraces of ravines, correspond to unsalinized zonal types of soils (in our case, to the southern chernozems). Under strips of pine forests (symbol for coniferous forests) are the characteristic weakly podzolized peaty soils.

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[1] We used the experience in compiling a soil map of Altai krai by N. I. Basilevich, I. I. Karmanov, V. I. Kravtsova, N. V. Orlovsk, A. N. Rozanov. The work was done in the Special Composite Expedition for Lands of the New Agricultural Reclamation of the Council for the Study of Productive Resources of the Academy of Sciences of the USSR.

The second tract is located on the Biysk-Chumyshkaya plateau in an area of leached chernozems. As a whole it is distinguished by the great uniformity of soil cover. Leached chernozems constitute the general background. The accompanying soils are dark-gray forest soils under forests, and meadow chernozems and meadow bogs in the river valleys. All these types of soils, clearly coordinated with definite forms of relief or types of vegetation, can be easily delineated on a topographic map. Each of them corresponds to a definite designation or combination of map symbols. All the forest contours may easily be considered dark-gray and gray forest soils; the bottoms of the valleys shown on the topographic maps as meadows are occupied by meadow chernozems, while the waterlogged tracts of the bottoms are meadow-bog soils. Cultivated tracts on watersheds correspond to leached chernozems, which are sometimes replaced by dark-gray forest soils on slopes with logged-off sites.

Similar work was carried out for the remainder of the natural regions. This made it possible to conclude that for the intrazonal distribution of soils related to relief and vegetation there are corresponding changes in the landscape shown on the topographic maps, and the contours of these soils may be distinguished by such changes. This conclusion is not restricted to soils on logged-off areas, where the cartographic representation of the landscape does not reflect the unique characteristics of the soil cover.

The following stage of the work consists in extrapolating the data obtained to the surrounding territory: that is, delineating the soil contours continuously over the entire area according to the topographic maps (even though there is no soil data supplied for the area). The basis for projecting the soil contours in this manner is the interrelation already found between the elements of the soil and plant cover on the topographic map and the actual soil types determined. For this purpose we most often use combined representations of separate elements of the landscape, not the simple symbols of the topographic map. The same conventional symbol of a kind of vegetation takes on a different meaning depending, for example, on conditions of the relief. In such cases it is natural to use a combination of designations of vegetation and relief: for example, the conventional symbol for meadow in a river valley corresponds to meadow-chernozem soils; the flood-plain of a great river to alluvial soils; and the terrace of a salt lake to somewhat salinized meadow-chernozem soils. It must be noted that the conclusions regarding the correspondence between certain conventional designations on the topographic map and definite soils are applicable only to limited areas of definite natural zones, subzones or regions. The same conventional signs from the topographic map, when found in different zones, naturally take on a different significance from the point of view of the distribution of definite types and subtypes of soils in these areas. Thus, the symbol for birch groves and large forests in the zone of chestnut soils and southern chernozems corresponds to solods; the same symbol in drained plateau tracts in the zone of the usual and of leached chernozems corresponds to dark-gray forest soils; while on the western slope of the Salair ridge, in the zone of the dark-gray forest soils, gray forest soils are widespread under forests. Just as the symbol "meadow" in the zone of chestnut soils on terraces near lakes and in river valleys usually corresponds to solonchaks

Relation between conventional signs on the topographic map and corresponding types of soils.

Conventional symbols for soil-vegetative cover	Relief	Soil-geographical zones and subzones	Types and sub-types of soils
Broad-leaved forests and birch groves	Slopes of ravines and valleys, interfluves	Dark-gray forest soils	Gray forest
		Podzolized chernozems	Gray and dark-gray forest
		Leached chernozems	Dark-gray forest
	Slopes of ravines and valleys	Ordinary chernozems	Dark-gray forest
	Depressions on interfluves	Ordinary chernozems	Dark-gray forest solodized and solodi
	Depressions on slopes of large hollows and ravines	Southern chernozems	Dark-gray forest solodized and solodi
	Depressions	Dark chestnut soils	Solodi
Sparse forest	Plains	Podzolized chernozems	Dark-gray forest
		Leached chernozems	Podzolized chernozems
	Mountainous regions	Mountain-forest zone of the northern Altai	Mountain-forest dark-colored chernozem-like
Conifers (spruce, pine) and mixed forest	Mountainous regions	Forest zone of the Salair ridge	Deeply podzolized forest
		Mountain-forest zone of western Altai	Mountain-forest gray
Conifers (spruce, larch) and mixed forest	Mountainous regions	Mountain-forest zone of Altai	Mountain-forest dark-gray
Meadow	Valley flats	Leached chernozems	Meadow-chernozem
		Ordinary and southern chernozems	Meadow-chernozem solonchak-type
	Depressions	Dark chestnut and chestnut soils	Meadow-chestnut
	Terraces around lakes	Dark chestnut and chestnut soils	Meadow solonchak
Meadow	Bottoms of narrow valleys, saucers, old, wet riverbeds	Leached and ordinary chernozems	Meadow-bog
		Ordinary and southern chernozems and dark chestnut soils	Meadow-bog solonchak-type
	Waterlogged basins of old lakes	Southern chernozems	Solodized meadow-bog
Meadow with hillocks	Valley bottoms	Ordinary and southern chernozems	Meadow solonchaks
Steppes	Level plains	Southern chernozems	Southern chernozems
		Dark chestnut soils	Dark chestnut
		Chestnut soils	Chestnut
	Depressions, basins	Southern chernozems	Solonized southern chernozem
		Dark chestnut soils	Solonized dark chestnut
		Chestnut soils	Solonized chestnut
	Intrazonal Types of Soils		
Impermeable solonchaks			Solonchaks
Solonchaks			Solonchaks
Steppes with solonchaks			Solonetzes
Bogs			Peat-bog
Pine forests	On sand dunes of ancient stream valleys		Weakly podzolized peat
Swamped pine forests	On valley flats of ancient streams		Peat-podzolic gleyed
Meadow	Floodplain		Alluvial-meadow

or strongly solonchak-like chestnut or chestnut-meadow soils, so the same symbol in the zone of leached chernozems corresponds to contours of meadow-chernozem soils (in valley bottoms) and of alluvial soils (in large river valleys). The symbols "bog" and "waterlogged meadow" may correspond to meadow-bog soils (in river valley bottoms in the zone of leached chernozems), or to peat-bog (along ravines in the pine forests of the east bank of the Ob river), or to meadow-bog salinized soils (on old terraces of the east Ob plateau with salty soils). The table shows the most characteristic cases of correspondence between the conventional symbols of the topographic and soil maps, depending on their combination with the relief and other descriptive characteristics and on the location of the area in a definite soil-geographical zone.

This is the way the topographic map shows a change in soil cover and gives us the shape (that is, the contour of various soil types) into which is fitted the content (in which the delineation of these types is carried out) read and interpreted on key tracts on large-scale maps and according to supplementary information—descriptions, investigations along routes, and data from the State Soil Map. The drawing of the "delineated" soil contours is done on tracing paper laid on the topographic map sheet; it is then reduced to the required scale and processed.

In order to judge whether the method of compiling soil maps which we used gives sufficient accuracy, detail and reliability, we compiled soil maps for five small control tracts (1600 to 3500 km.^{2}) distributed in various natural zones of the territory, and then compared and analyzed the maps thus produced. Using two different but parallel methods, we produced for each tract:

1. A soil map compiled on the basis of large-scale official material, chiefly photographic. We used this map in effect as a control, and on the basis of it evaluated the quality of the map compiled by the suggested method.

2. A soil map compiled according to the 1:100,000 topographic maps. Such a soil map shows the potentialities inherent in a topographic map when used for special cartographic purposes. It should be evaluated from several points of view:

a) Abundance of detail in characterizing soil qualities. What is under consideration here is the number of types (subtypes, species, and so on) of soils which may be distinguished according to the conventional symbols on the topographic map. Naturally, not all the soil varieties that this map scale would require shown and which are indicated in the legend can actually be delineated according to the topographic map. It is necessary to clarify exactly which types, subtypes, and species of soils are not indicated by the topographic map; whether supplementary materials are needed to delineate them; and when delineated, which types of soils can be placed on the topographic map.

b) The abundance and completeness of detail of the soil contours. It would appear that this question is unnecessary, since the compilation is carried out on a scale ten times as great as that required. But, in delineating the soil contours according to the topographic map, we naturally do not proceed in a manner as detailed as that with which elements of the landscape are rendered. Since the completeness of detail of the soil contours is considerably less, it is quite proper to question whether it is adequate for a 1:1,000,000 soil map.

c) Correctness of interpretation with respect to soil of the content of the topographic map contours. In comparing these maps with maps compiled according to large-scale soil materials, we may establish whether the "delineating indicators" were correct and whether the specified combinations of conventional symbols really correspond to the specified types of soils. This justifies the use of the proposed method of compilation.

A comparison of these two maps of key tracts (Fig. 1) shows that most soil types may be dis-

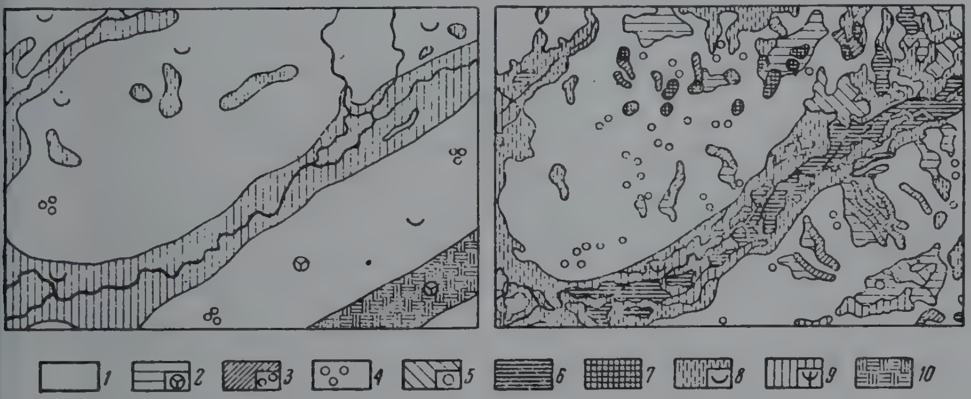

FIG. 1.—Comparison of a tract from the 1:1,000,000 State Soil Map with the soil map of the same area compiled by the use of topographic maps. 1—southern chernozem; 2—solonized southern chernozem; 3—dark-gray solodized forest; 4—solodi; 5—solonized solonchak meadow-chernozems; 6—solonchak meadow-bog; 7—solodized meadow-bog; 8—solonetzes; 9—solonchaks; 10—complexes of solonized chernozems, solonetzes and solonchaks.

tinguished on the bases of conventional symbols on the topographic map which have previously been delineated for their soil significance by comparison with individual tracts on large-scale soil maps. This conclusion does not apply to zonal types and subtypes of soils where a change does not lead to an abrupt transition in vegetation as rendered on the topographic map; therefore, we cannot delineate them according to this map. With respect to the types of intrazonal vegetation and salinization associated with special features of the relief, there is not a single case on any of the five tracts of the control map in which any such soil type is *not* reflected on the map made up from topographic materials.

The completeness of detail on maps made up according to topographic materials is so great that it must undergo considerable generalization before it can be put on a soil map. Therefore, there is certainly no danger in losing detail by the use of topographic maps. Rather, we may use as an example of the completeness of detail produced with the aid of these maps a soil map of Altai territory (see figure), in which is shown a sample compared with the same tract on the 1:1,000,000 State Soil Map of 1949.

The reliability of the map and correctness of the delineation of the contours require more fundamental consideration. In an analysis of the maps, we were convinced that the greater part of the contours had been correctly delineated; we also discovered a nonconformity of soil types delineated on the topographical and large-scale soil maps. These failed to agree either because of the fact that certain signs selected for the delineation of soil types were inadequate, or because the quality of the topographic maps was not high enough. This applies particularly to salinized and solonized soils. The degre of salinization and solonization is not rendered clearly enough by the topographic map. For example, in comparing the soil map with the topographic map, it was established that the symbol for "meadow" on low-lying lake terraces which had not long been above the surface of the water (as shown by the presence of saucer-like depressions and swamped tracts) corresponds to meadow solonchaks. And this is actually true for lake terraces of the central part of the Kulundinsk steppe. But the broad terraces of Kulundinsk lake, shown on the topographic map in exactly the same manner, are actually solonchak solonetzes. Thus this conventional symbol may be deciphered as "solonchak" only for a very limited region of the central Kulunda.

The correct results are not always produced by efforts to delineate the contours of these solonized soils: solonized chestnut, solonized southern chernozem, solonized ordinary chernozem. Sometimes they are erroneously associated with contours of non-solonized soils, and, on the other hand, they may be omitted, replaced by contours of general zonal types of soils. This occurs because the conventional symbol on the topographic map which corresponds to it—the symbol for virgin steppe in low-lying elements of the relief (basins connected with poorly drained defiles)—may also be related to non-salinized types of soils (on drained tracts). For this reason, when working with large-scale materials on key tracts, it is necessary to pay more attention to the regular patterns of distribution of these soils according to elements of the relief, while in delineating the contours special care must be used in analyzing the relief according to the topographic maps. Supplementary materials must also be used, especially the geomorphological map on which is shown the boundaries of lake terraces, valley bottoms, and tracts containing saucer-like depressions, which are associated with the development of salinized soils. Salinization is not clearly enough reflected on the topographic map in those places where special designations are used for it; thus, if the symbol for "solonchaks" almost always corresponds to the actual distribution of solonchaks, then the symbol for "steppes with solonchaks" (which usually corresponds to solonetzes) is not always used where it is needed. For this reason, on maps made up on the basis of topographic material, cases are found where solonetzes are shown in places for which the large-scale soil maps show solonized chestnut soils or solonized chernozems, or vice-versa; cases are also found where solonetzes are shown in valleys in place of solonized solonetz-type meadow-chernozems and vice versa. To avoid such errors, we must use the same methods as in the preceding case (careful analysis of the character of the relief, use of geomorphological maps in considering the regular patterns of distribution of the soils according to the relief). But all these discrepancies add up to a very small amount; the errors are made in both increasing and decreasing salinity. The use of supplementary materials, however, a creative approach to the compilation will, to a considerable degree, avoid such errors.

In conclusion, here are some notes on the selection of topographic maps. We used topographic maps published before 1946. On the new 1954 topographic maps, the conventional signs and classification of soil elements and vegetation cover are considerably expanded and therefore greater accuracy and completeness of detail for delineation of the contours would be possible.

However, use of the pre-1946 maps for our territory proved to be more expedient, since the land designated as "cultivated" on them was either non-salinized or included an insignificant proportion of salinized land. On topographic maps published after 1953, contours with solonetzes or solonized chernozems are designated on newly reclaimed cultivated areas. Furthermore, the differences in the salinity of the soils are reflected only in uncultivated areas with natural vegetation. These differences somewhat reduce their usefulness.

The evaluation of the timeliness and reliability of topographic maps must be unique. In each case these maps must be subjected to selective confirmation in the field for agreement with the determined soil types in order to establish the signs for the soil "delineation."

Our experience in compiling soil maps shows that the thorough use of topographic maps has great possibilities in creating special survey maps, making possible completeness of detail even when sufficient large-scale soil maps are not available. An indispensable condition in this process is an adequate study of the soil cover of the area and of the regular distribution patterns of the soil, such as we had in compiling the soil map of Altai krai.

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SALINIZATION OF SOILS AT THE PERIPHERY OF THE SOKH ALLUVIAL FAN

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THE occurrence of ground water and salts found at the periphery of the entire Sokh alluvial fan is due to their transport there by ground-water currents from higher zones where atmospheric precipitation and surface runoff (5) are absorbed and salts washed out (4). They also occur with the strongly mineralized water flowing in from artesian horizons of the lower strata of the underground water (2, 4, 7, 8, 11). In the zone of salt accumulation (4), the rate of inflow of ground water containing dissolved salts and the height of capillary rise to the evaporating surface (and consequently the rate of the salinization-desalinization process) is determined by the interaction of hydrostatic pressure and the factors which oppose it: resistance of the soil, downward-filtering currents, evaporation, transpiration and losses to adjoining soil areas (10, 3, 6).

Our established investigations were carried out in accordance with the soil-improvement regional classification of B. V. Fedorov in the third, or bamboo-solonchak zone (10) with a planned transition to the fourth zone of the solonchak plains. The purpose of the investigations was to determine which direction the soil-forming process takes under natural (that is, unimproved) conditions. They were conducted on the most productive collective farm of the Buvaidinskiy district, Fergana region. The farm is located on an irrigated area, characterized by soil which is not too suitable for improvement and which is subject to salinization. On the fields of the collective farm, which were occupied by cotton, grasses and tree plantings, fourteen "dynamic spots" were established according to Fedorov where observations were made on water and salt conditions of the soil and on the level and salinity of the ground water. Soil samples were taken and analyzed from depths of 0–5, 5–15, 15–25, 25–40, 40–60, 60–80, 80–100, 100–150, 150–200 cm., and so forth, down to the water table. Ground water was collected from the same borings deepened to 0.5 m. below the water table.[1]

Physical and Chemical Properties of Soil and Soil-water

The soil cover on the reclaimed parts of the area was represented by meadow soils, leached and for the most part slightly salinized, with fresh ground water located at a depth of two to three meters along watersheds and one to two meters on level portions. Experimental cotton and alfalfa fields were located on low-lying portions of the tract. Bog-meadow soil had developed on the depressions. On the unreclaimed areas meadow and crusted solonchaks had developed with strongly saline ground water. With respect to texture, the soil profile was stratified. From a depth of 60 to 150 cm. from the surface, the superficial clay loam and clay were interlayered with sand and clay with deposits of carbonates in the form of microconcretions and hard interlayers, called *arzyk*. Field moisture capacity (9) in the top one-meter layer of soil varied from 2670 to 2860 cubic meters per hectare; in depressions it was 3400 cubic meters per hectare when the water table was 170 to 220 cm. deep.

The soils of the unirrigated lands were characterized by chloride-sulfate salinization. The cationic portion contained magnesium, calcium and sodium. Ground-water anions were chloride and sulfate and its cations were calcium, sodium and magnesium.

Soils of the irrigated lands were characterized by sulfate, chloride-sulfate and less often chloride salinity; the cations were calcium and magnesium. There was extreme spottiness in the salinity of the soils, both in area and in the profile of an individual soil. Of the ground-water ions, sulfate predominated, while of the cations magnesium was sometimes more abundant than calcium and sometimes the opposite.

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[1] Editor's note: At each period of the analyses, the author took samples from one boring at each location; considering the well-known broad variation in the salt composition of salinized soils, even within the limits of a small, uniform tract, this method is inadequate. Thus, the author's data should be regarded as qualitative and his conclusions tentative. Great improvement is needed in the methods of dynamic investigation of salinized soils.

TABLE 1

Effect of the degree of soil salinization on the productivity of grasses and cotton.

Location No.	Soil under alfalfa	Date alfalfa cut	Hay crop, centners per hectare	Weight of dry roots in top 100 cm. soil layer ctr./ha.	Location No.	Soil under cotton	Plant density 1000/ha.	Stem height in cm.	Total raw cotton crop, ctr./ha.
1	Weakly salinized meadow	5/23/50	6.7	57.25	5	Weakly salinized meadow	83,000	90	33.2
7	same	same	44.0						
		7/4/50	37.2		11	same	95,000	100	27.0
		8/24/50	30.0		12	Medium salinized meadow	40,000	30	6.0
		9/28/50	21.3	202.5	14	Weakly salinized meadow	86,000	72	24.0
8	Solonchak spot	Almost complete absence of alfalfa plants							

Salinity of the irrigation water, which reached the collective farm from the Sokh river via the Buvaidinskiy irrigation canal, varied during the year from 240 to 528 milligrams per liter. The water led off by the collecting and drainage net from the land area of the collective farm by the Buvaidinskiy drainage canal and the Mul'kabad floodway was identical in its salinity and chemical composition with the ground water of irrigated tracts. With an increase in the degree of salinization of the soil and of the ground water, the productivity of plants decreased (Table 1).

The level of the water table in irrigated areas was complicated by local factors and influenced by the type of irrigation, with peaks corresponding to the stoppage in March and April and in the period June to August. In addition, separate, quickly declining peaks of ground water were observed caused by irrigation floodings. The amplitude of the fluctuation of the height of the water table in a year reached 80 to 100 cm. This level of the water table was observed in fields under cotton and in apricot orchards. Under alfalfa the water table sometimes failed to reach the summer maximum, or else was weakly developed.

Water Conditions in the Soil

Beginning in early spring (March and April) and proceeding up to the end of the growth period of cotton (September), the moisture storage in the soil, regardless of its periodic replenishment by irrigation, decreased, reaching a minimum in September. Thereafter, with a decrease in the loss of water by evaporation and transpiration, the quantity stored in the soil profile increased up to February or March. The rate and depth of the drying of the soil profile during the growth period depended on depth of water table and structure of soil profile. In areas where the water table fluctuated during the growth period between depths of 180 and 280 cm., drying out of the soil profile took place at a faster rate (Location 14) than on soils with a water table 160 to 210 cm. below the surface (Location 11). An intermediate position between these two with respect to drying out was occupied by areas with a more superficial water table at 150 to 180 cm., the root zones of which were underlain by layers of clay and large particles of sand (Location 5 and 6). A decrease in moisture content of the root zone (0 to 80 cm.) of the soil down to 70% of the field moisture capacity following irrigation in June, July and August took place in the first instance after 10 to 15 days, in the second after 25 or more days, and in the third after 15 to 20 days.

We did not observe a consistent decline of moisture stores in the soil under alfalfa with three to four waterings during the growth period, with the water applied in some cases at rates of more than 1200, 1700, and even 2200 cubic meters per hectare.

On areas of alfalfa with sparse plant cover having soil of stratified composition from a depth of 60 cm. (layers of marl clay or clay loam alternating with coarse particles of sand; Locations 1 and 2), with variation in depth of the water table from 130 to 170 cm., the capillary supply of water from below was diminished and considerable drying of the soil profile observed. A decrease in moisture content to 70% of the field moisture capacity was observed within 14 to 18 days of watering.

On alfalfa plantings with good plant cover and soil profiles of uniform texture down to 90 to 130 cm. deep, not underlain by coarse particles of sand and with less pronounced interlayers of marl, when the water table was from 200 to 250 cm. deep the capillary supply from below took place at a considerably higher rate (Location 7). The soil moisture was maintained at a higher level during the growth period and did not fall to 70% of the field moisture capacity until 30 to 50 days after watering.

Under the orchard, as under the neighboring cotton field, drying out of the soil began in early spring in the upper horizons, then encroached on the lower ones, reaching a maximum by the middle of July; under cotton the maximum was observed at the end of September. Drying of the soil under the orchard was more intense than under cotton. During almost the entire growth period, the moisture content of the top 25 cm. of soil under the orchard was considerably less than twice the maximum hygroscopicity, while in the 25 to 60 cm. layer the moisture content approached the hygroscopicity when the water table was at a depth of 180 to 240 cm. This showed that the evaporation of rising flow of salt solutions from the surface of the soil during the growth period was considerably diminished. From the middle of July the quantity of moisture lost through transpiration decreased, in August the water table rose and the moisture content of the soil profile under the orchard increased until February or March.

Salt Conditions

In early spring (March), with the thawing of the frozen horizons, the profile of the soil under cotton received the downward flow of fresh water which was maintained by falling atmospheric precipitation and by the April irrigation, which had a leaching action. With an increase in air and soil temperatures, the downward movement of the soil solution was replaced by a rising movement which, toward June, and before the first irrigation, led to the accumulation of salt in the top one meter of soil. The irrigations brought fresh water to the root zone of the soil, washing out the salts into the deeper-lying horizons down to the water table. The salts washed out by the irrigations moved with the rising flow of moisture to the surface horizons.

On cotton fields with well-developed plants, uniform texture of soil profile, a relatively deep water table (180 to 280 cm.) and relatively weak participation of ground water in the total evaporation, salt did not accumulate in the soil profile. In the periods between irrigations, outbreaks of salting were observed, but they were obliterated by three irrigations at the total rate of 2400 cubic meters per hectare (Table 2). The decrease in salinization of the ground water for the growth period and for the year as a whole was explained by the occurrence above the ground water of a less saline filtrate during irrigation. In the tables, the figures in the numera-

TABLE 2

Salt conditions in the soil and ground water under cotton. Location 14 with well-developed plants.

Date sample taken	Solid residue	Cl^-	$SO_4^{=}$	Ca^{++}	Mg^{++}	$Na^+ + K^+$ by difference	Remarks
6/5/50	0.900	0.031	0.500	0.120	0.030	0.083	Watered 6/11/50 @ 900 M^3/ha.
6/15/50	0.760	0.024	0.420	0.106	0.020	0.077	
7/5/50	1.000/1592	0.045/46.75	0.520/720	0.113/123	0.035/116	0.11/131	Watered 7/6/50 @ 1000 M^3/ha.
7/9/50	0.530	0.011	0.310	0.081	0.023	0.038	
9/2/50	0.689/1120	0.038/38	0.455/579	0.115/68	0.035/82	0.092/146	Watered 9/14/50 @ 500 M^3/ha.
9/29/50	0.567/784	0.016/66	0.300/286	0.085/76	0.016/72	0.043/88	
11/18/50	0.790/1392	0.033/52	0.420/675	0.097/142	0.033/130	0.080/117	Watered in January, 1951
2/26/51	0.765/1648	0.028/62	0.417/806	0.097/112	0.023/126	0.073/231	Watered during the 2nd and 3rd ten day periods of April '51
4/23/51	0.470/1252	0.028/51	0.240/546	0.061/94	0.015/76	0.05/203	Watered 6/12/51 @ 800 M^3/ha.
6/15/51	1.070/1380	0.055/107	0.630/559	0.123/120	0.03/84	0.148/230	

tor designate the salt content in the top 60 cm. layer as a percentage of the soil volume (salt content as a percentage of the weight of the absolutely dry soil multiplied by the weight by volume of the layer), while the figures in the denominator show salinization of the ground water in milligrams per liter.

On cotton fields with a relatively superficial water table (160 to 210 cm.) and a high rate of capillary supply of moisture from below to the soil profile during the growth period, the recurrence of salinization which took place between irrigations was not obliterated by three or four irrigations, and a supplementary accumulation of salts took place in the soil profile and ground water (Locations 11 and 12; see Table 3).

On cotton fields with superficial water tables (150 to 180 cm.), but with slight participation of the ground water in the total evaporation because of stratification of the soil profile (interlayers of clay and coarse particles of sand), with three irrigations during the growth period a weak supply of fresh water to the soil profile occurred at the locations where the cotton was better developed (Location 5), while negligible salinization occurred at the locations where the cotton was more poorly developed (Location 6). At both locations, salinization of the ground water was increased (Table 4).

On the three cotton fields mentioned, with salinization of the ground water varying during the growth period on the first field from 0.78 to 1.5 grams per liter, on the second field from 1.7 to 2.2 grams per liter and on the third field from 2 to 4 grams per liter, the critical level of the water table (12) at this period was at a

TABLE 3

Salt condition of the soil and ground water under cotton.

Date sample taken	Solid residue	Cl^-	$SO_4^=$	Solid residue	Cl^-	$SO_4^=$	Remarks
	Location 11			Location 12			
6/8/50	0.923	0.011	0.536	0.900/1448	0.017/55	0.45/777	
6/21/50	1.182/1864	0.016/62	0.690/1033	1.260/1296	0.022/37	0.75/609	Watered 6/23/50 @ 700 M³/ha.
6/26/50	0.980/2176	0.030/90	0.580/1242	0.960	0.024	0.59	Watered 6/29/50 @ 500 M³/ha.
7/8/50	1.280	0.011	0.770	0.980	0.026	0.600	
8/2/50	1.380/1712	0.077/45	0.820/905	1.580/1704	0.42/50	0.90/987	Watered 8/5/50 @ 1000 M³/ha.
8/10/50	1.260/1910	0.020/52	0.750/1057	1.400/3124	0.042/63	0.79/1892	
9/13/50	1.320/2176	0.022/44	0.760/1209	1.800/2168	0.051/52	1.080/1283	Watered 9/15/50 @ 180 M³/ha.
9/23/50	1.052/1792	0.018/52	0.640/839	1.130/2540	0.026/54	0.67/1465	Watered 9/20/50 @ 1040 M³/ha.
11/16/50	1.350/2264	0.024/64	0.750/1116	1.450/3052	0.038/82	0.83/1473	Watered 11/25/50
2/23/51	1.310/3240	0.028/52	0.740/1773	0.917/2488	0.031/51	0.560/1514	The field was not sown in 1951.
4/21/51	1.110/2332	0.014/43	0.750/1398	1.020/2176	0.008/54	0.647/1119	
6/14/51	1.233/3236	0.009/67	0.870/1886	1.170/3712	0.017/86	0.730/2065	

TABLE 4

Salt condition of the soil and ground water under cotton.

Date sample taken	Solid residue	Cl^-	$SO_4^=$	Solid residue	Cl^-	$SO_4^=$	Remarks
	Location 5			Location 6			
6/8/50	0.750	0.028	0.400	0.460	0.007	0.220	
6/21/50	0.870/2240	0.024/47	0.550/1341	0.610	0.010	0.310	Watered 6/23/50 @ 700 M³/ha.
6/27/50	0.820/2232	0.025/59	0.430/1374	0.890/3192	0.016/90	0.490/1863	Watered 6/29/50 @ 300 M³/ha.
7/8/50	0.570	0.008	0.330	0.800	0.012	0.48	Watered 7/23/50 @ 500 M³/ha.
9/9/50	0.400/4032	0.009/96	0.210/2337	0.660/4240	0.008/70	0.400/2411	Watered 7/28/50 @ 400 M³/ha.

depth of 200 to 280 cm. in soil with a uniform profile (Location 14), somewhat lower (160 to 210 cm.) in the second field (Location 11) and at a depth of 150 to 180 cm. in a stratified profile (Location 5).

The salt content in the soil profile under alfalfa was subject to less variation as a result of the better supply of fresh water to the soil and the ground water. On alfalfa fields with well developed plant cover, a relatively deep (200 to 250 cm.) water table and slight salinization of the ground water (0.8 to 2.0 grams per liter), but with active participation of the ground water in the total evaporation and with three to four irrigations during the growth period, the accumulation of salt in the soil profile was not observed (Location 7). Salinization of the ground water was not significantly increased (Table 5).

On alfalfa fields with scant development of plant cover, a superficial water table (110 to 180 cm.) and increased salinization of the ground water (2 to 4 grams per liter), but with a weak supply of capillary moisture from below to the soil profile because of close interlayering of the hard *arzyks* and coarse particles of sand, and with three or four irrigations during the growth period, an insignificant accumulation of salt took place in the soil at Location 2, which was poorly irrigated and with inferior plant development, while slight desalting took place at Location 1, which was normally irrigated and with superior plant development. Freshening of the ground water took place at both locations (Table 6).

Consequently, on these alfalfa fields, with salinization of the ground water varying in the first case from 0.8 to 2.0 grams per liter and in the second from 2 to 4 grams per liter, the critical level of the water table was 200 to 250 cm. for the first soil profile, with an abundant supply of water from below, while the level lay higher than 110 to 180 cm. for the second field where there was a poor supply of ground water from below.

Tree plantings made possible a good supply of

TABLE 5

Salt condition of the soil and ground water under alfalfa.

Date sample taken	Solid residue	Cl^-	$SO_4^{=}$	Solid residue	Cl^-	$SO_4^{=}$	Remarks
	Location 7—better developed plants			Location 8—solonchak microelevation			
5/31/50	0.315/864	0.012/21	0.174/395	1.917/808	0.036/31	1.180/372	Watered 6/2/50 @ 400 M^3/ha.
6/5/50	0.590	0.012	0.346	2.300	0.037	1.416	Watered 6/4/50 @ 700 M^3/ha.
7/12/50	0.384	0.016	0.188	1.370	0.019	0.815	
8/19/50	0.486/1300	0.016/31	0.265/773	1.270/1488	0.020/31	0.810/790	Watered 8/28/50
8/30/50	0.385/632	0.010/21	0.195/303	1.700/1908	0.023/49	1.050/963	Watered 8/28/50 @ 630 M^3/ha.
9/21/50	0.570/1792	0.015/63	0.315/963	2.040/1736	0.067/42	1.250/922	
11/18/50	0.480/2172	0.010/38	0.260/1094	1.300/1660	0.016/45	0.760/855	
2/24/51	0.306/904	0.012/17	0.160/403	1.780/1680	0.040/42	1.030/823	
4/23/51	0.450/948	0.016/29	0.228/458	1.630/1864	0.027/39	1.040/905	
6/14/51	0.330/1288	0.014/36	0.170/464	1.400/1248	0.025/38	0.965/494	

TABLE 6

Salt condition of the soil and ground water under alfalfa.

Date sample taken	Solid residue	Cl^-	$SO_4^{=}$	Solid residue	Cl^-	$SO_4^{=}$	Remarks
	Location 1			Location 2			
5/22/50	0.366	0.007	0.201	0.580/3328	0.013/66	0.350/2098	Watered 6/7/50 @ 1200 M^3/ha.
6/11/50	0.593/4100	0.008/110	0.305/2604	1.030/3720	0.060/86	0.015/2032	
7/4/50	0.475/3584	0.020/59	0.228/2246	0.710/3720	0.011/86	0.430/2263	Watered 7/29/50
8/17/50	0.326/3872	0.003/71	0.148/2126	0.920/3024	0.033/40	0.480/1770	Watered 8/23/50 @ 1200 M^3/ha.
8/26/50	0.305/3192	0.005/49	0.130/1852	0.970/2984	0.019/35	0.580/1695	
9/26/50	0.290/2100	0.005/30	0.140/1382	0.800/2840	0.021/66	0.465/1514	
11/16/50	0.415	0.006	0.205				
2/23/51	0.665/3064	0.027/42	0.340/1703				
4/21/51	0.316/2540	0.009/51	0.160/1484				
6/14/51	0.250/3480	0.006/80	0.118/2061				

fresh water to the soil and ground water. There was an insignificant content of salts in the soil and ground water and it changed very little during the growth period and with irrigation, when the depth of the water table was 180 to 240 cm. The degree of salinization of the ground water corresponded directly to the depth of the water table. When the level of the water table fell between spring (April) and fall (November) salinization of the ground water decreased, whereas when it rose between November and April salinization also increased.

Conclusions

1. Stratified formations of the peripheral portion of the alluvial fan have developed the properties of a "stratified screen," as manifested by a slowing of the capillary rise of moisture. Consequently, the capillary rise cannot keep up with evaporation, and a reversed movement of the salts (which are leached during irrigation) takes place at a slower rate. The existence of a local outflow of ground water via the sandy drainage layers led during irrigation to the formation of soils and ground water which were slightly salinized, or, more seldom, of medium salinization.

2. The accumulation of salt in the soils or ground water begins to predominate over desalinization under the crops studied, with existing agricultural methods and salinization of ground water, at a definite and critical level of the water table:

a) Under cotton, the critical level of the water table on stratified soils in which the ground water takes only a small part in the total evaporation is 150 to 180 cm. when salinization of the ground water is 2.2 to 4.0 grams per liter; on uniform soils, with ground water salinization varying between 0.8 and 1.5 grams per liter, the critical level is 200 to 280 cm.

b) Under alfalfa on stratified soils, with salinization of 2 to 4 grams per liter and with only slight participation of the ground water in the total evaporation, the critical level of the water table is 110 to 180 cm.

c) On tracts in which the ground water participates actively in the total evaporation under cotton with salinization of the ground water of 1.7 to 2.2 grams per liter the critical level of the water table lies below 160 to 210 cm.; under alfalfa with salinization of the ground water of 0.8 to 2.0 grams per liter, the critical level is 200 to 250 cm.

d) Under orchards the critical level of the water table is at a depth higher than 180 to 240 cm. when the salinization of the ground water is 0.8 to 1.5 grams per liter.

3. To act on the soil-forming process as far as desalting is concerned, it is necessary, under existing natural and economic conditions, to keep the water table 25 to 50 cm. below the critical level (depending on the structure of the soil profile). Such a decrease in the depth of the water table will not cause a complete disconnection of the capillary fringe from the root zone and will support meadow conditions.

4. The recommended figures for depths of the critical levels of the water table apply to most of the irrigated lands of the bamboo-solonchak plains situated at the periphery of the alluvial fans of the rivers Sokh, Isfara, and others.

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SOILS OF THE WESTERN PAMIR

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Up to the present time soil investigations in Badakhshan (Western Pamir) have been limited to descriptions of routes and irregular investigations of separate agricultural regions. Besides the clearly obsolete articles of S. S. Neustruyev (7) and M. A. Orlov (8), the only summaries purporting to furnish general material on the soils of the Pamir (including Badakhshan) are those of V. N. Ivanov (5, 6), which furnish in some detail isolated material from his own investigations. In the absence of other material, this would have been of considerable value if the author had not limited himself in his routes to the usual paths along rivers or if he had attempted to give a characterization by vertical zones. Since the basic objective of Ivanov's investigations was to study the prospects for agriculture, he naturally concentrated most of his attention on the valleys. The characterizations of the arable lands of terraces and areas set forth (6) in his descriptions of soil sections were often arbitrarily extended by the author to zonal soil groups. There is clearly insufficient basis for such generalizations. The soils of most of the area of Badakhshan—the slopes and watershed areas—remained unstudied.

Evidently, Ivanov's papers were subsequently used by A. N. Rozanov (10) in composing a short article on the soil resources of the Tadzhik Socialist Soviet Republic. To this article was appended a 1:1,000,000 soil map, which is the only more or less detailed map reflecting zonal distribution of soils in Tadzhikistan. According to the planimetric data of the map, the article estimates the areas under various soils for each region and for Tadzhikistan as a whole. The other published soil maps that include the Tadzhik SSR are small-scale survey maps appended to various textbooks or teaching manuals or included in geographical atlases.

When we compared the existing literature and cartographic material on the soils of Badakhshan with data from our own three years of observation in this area, we concluded that insufficient factual information was responsible for widespread errors concerning Western Pamir soils. Since cartographic material most graphically reflects our knowledge of various areas, we will concentrate on a survey of it.

1. Rozanov's map for Badakhshan distinguishes the following soil varieties:

a. Mountain sod-burozem soils, covering the lower part of the slopes of the Pyandzh valley (below Khorog), and also the lower reaches of the Gunt, Bartang, Yazgylem and Vanch rivers;

b. Mountain-meadow-steppe brown soils of the subalpine zone;

c. Mountain-meadow peat-sod soils of the alpine zone.

2. The Soil Map of the USSR in the Great Soviet Atlas of the World (Vol. 1, 1937, pp. 115–116) shows mountain-meadow soils for Badakhshan.

These same mountain-meadow soils also cover all of Badakhshan on the numerous survey maps, of which the following examples are cited:

a. Soil Map of Non-Soviet Asia (which includes not only Afghan but also Soviet Badakhshan) at a scale of 1:20,000,000, appended to the book "Non-Soviet Asia" (2) and compiled by a group of specialists under the editorial direction of E. N. Ivanova.

b. Soil maps of the USSR and of the world on a small scale, assembled on the basis of materials at the Soil Institute and appended to various textbooks and teaching manuals.

3. The Soil Map of the USSR (scale 1:30,000,000) from the Geographical Atlas for Teachers in secondary schools (1954) shows for Badakhshan:

a. Mountain-steppe soils (the western part of Badakhshan);

b. Mountain-meadow soils (the eastern part of Badakhshan).

4. The Soil Map of the Soviet Union on a scale of 1:4,000,000, published by the Soil Institute of the Academy of Sciences, USSR, under the editorial direction of I. P. Gerasimov (compiled by N. N. Rozanov and Ye. V. Lobova) shows mountain meadow-steppe soils for Badakhshan.

Let us examine the maps just enumerated, which are widely used not only by specialists but also (and this is especially important) by young students, and see how closely they correspond to reality.

The soil types listed above were entered on Rozanov's map undoubtedly on the basis of extrapolation from the soils of Central Tadzhikistan (Kuhistan), of which some studies have been made. All the contours of the map, without exception, were simply "stretched out" from Kuhistan over Badakhshan and their outlines determined by hypsometric contour lines. Moreover, this process did not take into consideration the difference in natural and climatic conditions between Badakhshan and Kuhistan—a difference so great that it alone would make it impossible for uniform zonal soil groups to exist in these regions.

Badakhshan is a natural arid region where the amount of annual precipitation varies between 90 and 217 mm., while for Kuhistan the corresponding figures are 544 and 900 mm. The aridity leads to the development in Badakhshan of generally desert and desert-steppe types of vegetation, including "prickly grasses" (*kolyuchetrav'ye*) and "prickly cushion plants" (*kolyuchepodushechniki*). Kuhistan, on the other hand, is characterized by the wide distribution of trees, shrubs, and meadow vegetation. It is understandable that under these conditions (and their characterization could have been made considerably broader) the existence of the soil types in Badakhshan shown on the map is impossible.

Mountain sod-burozems are actually encountered in small spots only on the lower reaches of the Vanch, while the area which they occupy on the map is characterized by undeveloped dark sierozems. Since this zone is dominated by loose groups of *Artemisia*, which include other xerophytic plants, the formation of sod is practically impossible here.

Mountain meadow-steppe brown soils of the subalpine zone (occupying about 20% of the area of Badakhshan on Rozanov's map) in practice play an insignificant role there, since there is no subalpine zone with its tyical mesophilic tall meadow herbage in the Western Pamir; in arid conditions and under the scattered xerophytic *Acantholimon-Artemisia* vegetation that covers the intermediate zone of Badakhshan, such soils cannot be formed. Bits of mountain-meadow soils are found here only on terraces where moisture is supplied by ground water or on sloping tracts watered by springs, but these soils occupy a limited area and do not form zones. Actually, the area of the intermediate zone is occupied by many types of stony-gravelly high-mountain soils evidently similar to the gray-brown (1) soils of the Eastern Pamir. Steppe variants of these soils are associated with limited areas on the thinly-peat areas of eastern and southern slopes.

Mountain-meadow peat-sod soils of the alpine zone also do not have zonal distribution in Badakhshan and are represented only by small wet tracts in depressions and on flood-plains of mountain rivers and streams, but Badakhshan has no alpine zone with short meadow herbage. The high mountain regions are practically devoid of soil, and are covered with stones and gravel in the initial stages of soil formation. Sod cannot be formed here, since on this kind of ground with scanty atmospheric moisture there develops at most scanty cryophilic vegetation represented by isolated groups or individual plants—cinquefoil, draba, edelweiss, *Oxytropis*, cushion plants, and so forth. The formation of sod, or even less of peat, is out of the question on most of the high mountain massifs of Badakhshan.

Thus, the extrapolation carried out for Badakhshan is based on false conceptions of it. It is not surprising that in the planimetric indications of this map (10), the Gorno-Badakhshan autonomous region is devoid of rocky slopes (whereas these, with stone outcroppings, occupy no less than 70% of its area) and rich in productive mountain-meadow soils (of which there are in reality none).

The erroneous indication of mountain-meadow soils for Badakhshan in the Great Soviet Atlas of the World (3) occasioned repetition of this error in other soil survey maps, some of which are enumerated above. This gives students a theoretically false idea of the Western Pamir in that predominance by mountain-meadow soils presupposes a certain humid natural complex which actually does not exist.

The designation in Badakhshan of mountain-steppe and mountain-meadow soils in the Geographical Atlas for Teachers in Middle Schools (4) is evidently based on Rozanov's map (10). As evidence for this, the generalized designations in the legend of this map and the approximated contour outlines may be cited. Future compilers of soil survey maps will in all probability also rely either on Rozanov's map, as the only large-scale soil map of Tadzhikistan, or on the soil map in the Great Soviet Atlas of the World, which was based on obsolete material. These errors will therefore be compounded many times. They not only lead to unsound concepts regarding the geography of the Western Pamir as a whole, but confuse agricultural planning organizations that are engaged in working out agricultural systems in the various zones. In order to avoid this, a project should be developed as soon as possible for a uniform soil survey and mapping of the Pamir.

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SOILS OF WRANGEL ISLAND

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Wrangel Island is located in the zone of arctic desert and has an area of 7673 square kilometers. Strongly dissected mountains and plateaus of the central part of the island occupy about two thirds of its area and have an average elevation of 500 meters and isolated peaks reaching higher than 1,000 meters. From the north and south they are adjoined by slightly sloping accumulative littoral plains. Most of the flat area is covered by arctic desert which is replaced, in the northern part of the island, by very sparse arctic tundra. Arctic desert, rock vegetation and beds of rubble predominate on the mountains.

Soil formation on Wrangel Island has a number of unique features. It takes place under extremely severe conditions for plant growth. The development of plants is hindered both by the shortness of the warm period of the year, during which the air temperature is low and frosts can occur on any day, and by the extremely small amount of precipitation which is approximately 200 mm. a year. The thinness of the snow cover and its uneven distribution protect the vegetation only poorly from corrasion by the snow and the soil from weathering. For this reason the plants almost nowhere form continuous cover. They are extremely low-lying and provide a very small annual increase in organic matter. Depending on the thickness of the soil cover and the moisture content, the plants settle individually on the surface of the bare, convex polygons and form loose sod or in places tufts or beds of plants in the broad troughs between polygons. In places with heavy snow cover, for example at the foot of hills, they completely cover the polygons leaving bare the narrow, steep-walled troughs between them.

In the formation of the soil profile, physical processes emphatically predominate over the biological. The structure of the soil horizons is constantly changing under the influence of freezing and solifluction. The surface horizons of the soil which are not fastened down by continuous plant cover are periodically split off and violently destroyed by wind and surface water.

The ragged plant cover and numerous cracks in the soil would allow us to expect fairly good aeration of the soil and consequently quick mineralization of organic remains, and this should cause a reaction close to neutral. But in the arctic desert, the raggedness of the plant cover and the clearly manifested polygonal microrelief cause extreme spottiness of the soil cover.

Judging by the existing but scarce descriptions (Z. I. Yashina[1], B. N. Gorodkov [1, 2]), the soils of Wrangel Island actually have a number of specific characteristics: a shortened soil profile, very often consisting of a single A_0 or $A_0 + A_1$ horizon lying on the unchanged parent material; the absence, or the presence in only small spots, of a gleyed horizon; abrupt variations in the thickness of the soil horizons, discontinuity of their spatial distribution, and the partial absence of the upper horizon; and neutral, or nearly neutral, soil reaction. On Wrangel Island the different soil complexes are essentially very widely distributed as a result of sharp differences in the structure of the plant cover on the surfaces of the polygonal microrelief.

Thus there appears to be justification for defining a special arctic type of soil formation and, consequently, an arctic type of soils. E. N. Ivanova (3) comes to the same conclusion on the basis of data from soil investigations in the western sector of the Soviet arctic. These soils reflect the special character of nature in the arctic just as the tundra soils reflect nature in the subarctic, the podzolic soils reflect nature in the taiga zone, and so on.

Existing material allows us to delineate at present on Wrangel Island: arctic polygonal soils, arctic sod soils, arctic gley soils, bog soils, and mountain arctic soils.[2]

The rubble on the mountain tops and sand and gravel marine deposits occupy a special position on Wrangel Island:

The *rubble* is widely distributed on the slopes and tops of the mountains of the island. Rubble, consisting of large stones from fragments of sandstones, quartzites and magmatic rocks with diameters up to 1.5 m., is formed on mountain tops from the 400 to 600 m. bench marks and above. Rubble consisting of smaller stones and leaf-shaped chips is formed at altitudes of 300 to 400 m. As it slides down the slopes, the coarsely fragmented material is abraded; the proportion of finer material in the rubble gradually increases and at altitudes of 250 to 300 m. the proper conditions are created for the settlement of flowering and bushy lichens under which arctic soils are formed.

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[1] The author extends his sincere thanks to Z. I. Yashina for agreeing to the publication in this paper of some of her data.

[2] It should be understood that this classification is only preliminary. There are already too many meaningless soil observations on Wrangel Island.

Recent *sand* and *gravel marine deposits* are devoid of vegetation (zone of action of ice and surf during stormy periods) and are scattered in narrow belts along the shores of lagoons where they form bars and reefs.[3]

Arctic Polygonal Soils. These are soils of the most severe locations. They are formed on tracts of littoral lowland plains, intermountain troughs and terraces of large river valleys where less than 50% of the area is covered by vegetation and there is extreme variation in moisture content (from too little to too much). Texture and mobility of the subsoil, as well as the position in the relief explain the various types of vegetation. Arctic polygonal and arctic solonchak polygonal are subtypes which can be properly delineated.

General Characteristics. Arctic polygonal soils have a primitive structure. There is either no clay horizon at all in their profile (as determined visually) or only a poorly expressed one. Aside from the ragged cover represented by individual grassy plants and sometimes by lichens (horizon A_0) there is usually, but not always, a humus horizon (horizon A_1) with a low humus content either underlain by unaltered parent material (horizon C) or shading into parent material through a gley horizon (horizon G) which is weakly manifested in the form of spots. Often it is impossible to distinguish any other soil horizons except A_0. It is in just these soils that formation of polygons and mounds takes place at a high rate. Yashina's analyses give some idea of the textural and chemical composition of the arctic polygonal soils. Thus, for example, analysis of the bare portions of the polygons of the arctic polygonal soil on the surface of the alluvial-deluvial plains north of Ushakovskii showed that the texture of various horizons is not uniform. There is a high proportion of sandy fractions (up to 30%) on the surface. Gravel and detritus are concentrated in the layer from 20 to 40 (or 50) cm. Below, there is a clear increase in the quantity of silt, while the gravel and detritus are evenly distributed. The soil reaction at the surface is close to neutral (pH 6.80), while from depths of 30 to 50 cm. it becomes weakly alkaline (7.23 to 7.16).[4] The humus content of the surface horizon in such soils is small (1.77 to 2.66%) and disappears abruptly with depth. It is interesting to note that in some soil profiles a layer is found at 50 cm. with the same humus content (1.72%) as at the surface (1.77%). In the soils of the bare portions of the polygons Yashina detected a varying (11 to 23 milligrams per 100 grams) content of absorbed cations.

Arctic polygonal soils have a low content of nitrogenous compounds. They have slightly more phosphorus content. On the surface of the bare spots the amount of nitrogen is small (0.14 to 0.19 milligrams per 100 grams) and at a depth of 20 cm. it decreases to 0.11 milligrams per 100 grams. The phosphorus content is 7.5 to 12.5 milligrams per 100 grams.

As already stated, arctic polygonal soils are widely distributed on the littoral plains and bottoms of the intermountain troughs and on the lower areas of mountain slopes and plateaus of Wrangel Island. Here they are formed under various kinds of arctic deserts. Depending on the locality, the thickness of the snow cover, and the extent of soil moisture the basic arctic type of soil formation may take on a more or less definite characteristic of waterlogging with the result that various arctic gleyed soils are formed.

Arctic polygonal soils are formed under the bare, convex parts of polygons about one or two meters in diameter with moderate moisture and thin snow cover, or, more seldom, along the cracks between such polygons. Vegetation on the polygons is either completely absent or is represented by individual grassy plants or lichens. The humus horizon of these soils is thin (1.3 cm.) or very often completely missing. Underneath is found apparently unaltered parent material.

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[3] In the mountainous parts of the island are found small spots of clay-rubble and rubble-clay subsoils on areas of especially intense snow corrasion on the brows of slopes, the tops of hills, and the brows of highland terraces. They are not widely distributed.

[4] The time when Yashina took these soil samples is not stated.

The texture of the parent material and the position in the relief exert a substantial influence on the morphology of arctic polygonal soils. Thus, the arctic polygonal soils of the detritus-and-clay deserts on the fine-textured clay loam of the littoral plains have thin (1.3 cm.) very friable sods of grassy plants with some moss and lichens. The dark or yellow-brown clay loams found beneath them are not superficially different from the parent material.

On coarse-textured sandy loams under individual grassy plants and lichens on the sloping fluvioglacial plain the soil profile is not, as a rule, divided into horizons. It is entirely light-brown, with small pores (in the upper 2 to 5 cm.), and compact. In the upper layer, about two to three cm. thick, are seen most of the roots; below this they are very scarce.

Arctic Polygonal Solonchak Soils. These soils are scarcely different from arctic polygonal soils in their profiles. The periodic accumulation of easily soluble salts is seen only on the surface horizons. They owe their salinization both to the transport onto land of wind-driven splashes from the ocean ("pulverization") in shore areas and also to the accumulation of salts formed in the destruction of rock on the lower parts of the slopes and at the foot of elevated areas (4). The author had occasion to encounter saline efflorescence on the soil surface under snow meadows and sometimes under flood-plain meadows after a month-long drought at the end of June, 1952. The areas with efflorescences under snow meadows were located at the foot of slopes where, in winter, comparatively small snowpacks accumulated. Melting only in the middle of summer, they prevented the development of plant cover on the arctic polygonal desert; instead, extremely scanty mossy-grassy snow meadows were formed. The snowmelt quickly dried up and then the meadows were watered by a slight flow of ground water from the slopes. The intensified insulation of the solar day and the absence of rain for a whole month caused more rapid evaporation of the salt-carrying ground water, with the result that efflorescences were formed on the tops of small mounds five to ten cm. in diameter. They consisted of a tasteless white deposit[5] on the surface of individual peds which was denser on the southern exposures. There were no deposits on the surfaces of the peds facing the ground. Efflorescences have also been encountered under sparse flood-plain meadows under much the same circumstances.

No investigation was made of deep salinization of the arctic polygonal solonchak soils, since the snowmelt and rainwater carry the salts off to the rivers (or the ocean).

Arctic Sod Soils. These are formed on subsoils of coarse texture and mostly sandy loam and clay loam with a moderate moisture content and snow cover sufficient to protect grasses from corrasion. Such conditions on the largest areas are present on the piedmont tracts of the littoral plains, on terrace plains, and in the valleys of the large rivers. Arctic sod soils develop under sodded tracts of arctic polygonal deserts (slopes of polygons and the depressions between them) and under arctic meadows. Arctic sod soils are further subdivided into the arctic sod soils *per se,* arctic sod carbonate soils, and arctic sod illuvial-humic soils.

In the arctic sod soils, along with a porous sod up to 4 cm. thick from lichens, angiosperms and mosses, sometimes there was a peaty, fairly clearly delineated humus horizon below (horizon A_1) under which lay a brown clay loam (horizon B). Less often one sees under horizon A_1 of the arctic sod soils weakly developed and scanty dark-bluish spots and intrusions, evidences of slight gleying.[6]

Our description of soil from the slope of the right bank of the Tundrovaya river is given as an example of arctic sod soils:

Section 4. Site: Gently sloping surface of the right bank of the Tundrovaya river 350 m. south of the confluence with the first tributary on the right after the emergence of the river into the Academy tundra. Microrelief: Bulging mounds about one meter in diameter and 20 to 22 cm. high, with depressions between them of about the same area. The highest parts of the mounds (about a quarter of the total surface) had been subjected to snow corrasion and were devoid of vegetation. The area covered by vegetation, which amounted to about 75% of the surface area, consisted of the sides of the mounds and the lepressions between them. There were two layers of plant cover:

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[5] In the absence of hydrochloric acid it could not be established whether this was lime.

[6] It did not appear to be possible to get samples of arctic sod soils for analysis.

Layer I, 22 to 25 cm.: Grasses, sedges, mixed grasses, *Artemisia* spp. Occasionally individual willows. Vegetation not continuous; 75% cover.

Layer II, 1 to 3 cm.: Moss and lichens; 10 to 15% cover. The holes of lemming burrows are found on the mounds. Section goes through the mound and the depression.

A_1, 0 to 3(10) cm.: Cinnamon-brown, clay loam, moist, with fine clods, fine pores, and fine fissures. Mass of plant roots, no fauna, compact, borders sharp but uneven. Cinnamon color in the cracks (humus penetrates to a depth of 10 cm.).

B, 3(10) to 40(50) cm.: Light-brown, clay-loam, with individual particles of quartz gravel up to 3 mm. in diameter, wet; structural separates with ridges from 1 to 10 cm. Particles not prominent; fine pores and fine fissures, compact. Disintegrated to form a cavity 3 x 5 x 10 cm. lying mostly horizontally. The color of the walls of the root channels changed from light-brown to gray dark-blue at a depth of 1 to 3 mm. Such channels are usually vertical. The number of roots decreased noticeably with depth. At the lower boundary of the horizon were seen cinnamon-colored spots usually extending horizontally. They were 1 to 4 cm. in size. There were hardly any large roots in them. The boundary of the horizon was sharp.

A_1, 40 to 50(51) cm.: Buried, dark-brown to black, with a boggy odor, sandy loam, individual angular chips up to 4 cm. Upper half-centimeter layer with high content of quartz and sandstone gravel, quite moist, mass of rotted and half-rotted roots with shapes preserved. This horizon was frozen below 51 cm.

On the surface of the arctic sod carbonate soils of Wrangel Island, the periodic accumulation of carbonate salts in the form of small inflorescences takes place in summer under the influence of intensified insolation and insufficient surface moisture. These soils develop under arctic tundra and arctic meadows on tracts located near streams of the third or fourth flood-plain terraces in areas of lower Permian carbonate rock. The arctic sod carbonate soils do not occupy a large area. On one tract there are usually not more than several square dekameters. An exception to this is the area of the Neizvestnyi ("Unknown") river valley in the Severnye ("Northern") mountains, where these soils have developed on an area of several square kilometers.

Arctic Sod Illuvial-humic Soils. These soils are of great interest. On Wrangel Island they are formed in coarse and light rock (gravel, sand, sandy loam) under the plant cover of the arctic meadows and lichen-grass deserts of stream banks and river valleys. They have a fairly thick humus horizon (10 to 20 cm., sometimes more), underlain by a cinnamon-brown horizon with an admixture of pebbles, sometimes containing crumbled concretions of sesquioxides (horizon B).

The arctic sod illuvial-humic soils of Wrangel Island have been subjected to intensified wetting coupled with thorough warming, which has created favorable growth conditions for the plants settling on them. Such areas are found on tracts containing the burrows of lemming families, stream banks, and in the valleys of large rivers. We have described a section of such illuvial-humic soil from the third flood-plain terrace of the right bank of the Tundrovaya river after its exit onto the plain at the mouth of its first tributary on the right.

Section 2. Located on the even surface of the streamside embankment of the second terrace above the flood-plain 3 m. from the edge and 60 m. west of the bed of the tributary of the Tundrovaya river. The scanty mossy-grassy cover, not forming a cohesive sod, extends over the surface of the entire bank. The soil is covered with mosses (up to 1.5 cm. high), leaves around the roots, grasses and lichens (up to 5 cm. high). The second layer above the surface (up to 25 cm.) consists of the stems and flower-bearing shoots of grasses, *Artemisia* spp. and mixed grasses. About 60% is covered. Lemming burrow holes, marked by mosses and *Araneae* spiders, are found on the surface.

A_0, 0 to 1 cm.: Friable, poorly cohesive sod from the roots of seed plants and parts of plants which have frozen and fallen off.

$A_1 + B$[7], 0 to 41 cm.: Brown-cinnamon, even, fresh, sandy loam with an admixture slightly rounded, mostly flat pebbles of slate, sandstone and quartz from 0.3 to two or three cm. in size, fine-grained (ribbing of particles, 1 to 2 mm.), fine-pored, friable. There are no inclusions or new formations. The horizon is penetrated by a great mass of roots, the quantity decreasing with depth. The roots give the surface portion of the horizon a considerable density; when peds are tossed from a spade they do not break into smaller lumps. In the 0 to 5 cm. layer, larvae of insects were found. The border is clearly marked.

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[7] It is exceptionally difficult to distinguish horizon A_1 from B, so they are described together here.

C_1, 41 to 61 cm.: Comparatively well-rounded stones (3 to 4 cm.), with an admixture of gravel and sand. Individual rocks of prismatic form are found with ribs up to 8 cm. Pebbles, gravel and coarse sand amount to 40 to 50% of the total. Almost no fine soil, moist. In the upper 10 to 15 cm. of the layer plant roots are found. The boundary is clearly marked.

C_2, 61 to 79 cm.: Light-brown coarse-grained sand with gravel and no pebbles, moist, almost without fine soil. Frozen below 79 cm.

Arctic Gley Soils. These Wrangel Island soils are formed on arctic polygonal desert on tracts covered 60 to 80% by vegetation with subsoils of medium or fine texture having a moderate or slight excess of surface moisture. They are located chiefly on piedmont tracts of the littoral plains, at the foot of mountains in intermountain troughs, and in the valleys of large rivers having small plano-convex microrelief. Two types of soils are represented: the arctic gley-sod and the typical arctic gley soils.

General Characteristics. Of all Wrangel Island soils, the arctic gley soils have the most complex profile. Above the surface is a cover of moss, grassy plants, lichens and individual bushes; beneath them is a humus horizon (A_1), 5 to 15 centimeters thick, with a comparatively high humus content—about 5% and sometimes even higher. The existence of a humified, transitional horizon A_2B or B with signs of material being washed into it depends on the soil texture and the moisture conditions, and this horizon is not always present in the soil profile. The gley horizon below it (G) is manifested in varying degrees. It may be noted as a general tendency that the finer the soil texture and the greater the amount of water retained the more clearly the signs of gleying are manifested and the thicker the gley horizon becomes varying from 15 to 40 cm. The gley horizon usually goes over into the parent rock material (horizon C). The remaining boundaries of the horizons of the soil profile are clearly developed.

One of the peculiarities of the water conditions in arctic gley soils is the washing of their surface horizons by snowmelt and rainwater. The penetration of rain into the soil is facilitated by the numerous cracks caused by drying out.

The fairly wide distribution of carbonate rocks in the mountainous portion of the island favors the accumulation of humus in the surface horizons of the soil in broad river valleys and in piedmont portions of the littoral plains to which carbonates may be transported by snowmelt. However, not much carbonate is evidently transported and the solid grainy structure which is usual for the dark-colored sod-gley-podzolic and sod-gley soils of the forest zone does not occur in the arctic gley-sod soils of Wrangel Island.

Yashina's particle-size analyses of a number of samples of arctic gley soils in the vicinity of Ushakovskii, taken from depths of 0.5 to 50 cm., showed that on the sloping littoral plain of the southern shore there are widely distributed clay loams and clays of the sandy-silty type in which the silt fraction (0.01 to 0.001 mm.) amounts to 50 to 90%. The silt particles are most widely distributed in the medium clay loam and in the middle of the plains. In the depressions between the polygons the silt fraction amounts on the surface to 50% of the soil mass; the sand to about 25%; and the remainder is detritus and gravel. The silt content of the subsoil increases sharply with depth. The mineralogical composition of the subsoil is identical to the composition of the rock in its original stratum.

The arctic gley and polygonal soils of Wrangel Island are formed under the influence of freezing processes. However, the role of freezing in determining the structure of the soil profile is considerably less with arctic gley soils than with arctic polygonal soils. Ivanova (3) considers that the arctic gley soils are characterized by periodic (fall and winter) drawing up to the surface of the products of weathering (easily soluble salts, carbonates, sesquioxides). Yashina's analyses showed that in general the reaction of these soils is close to neutral; the surface horizons (A_1) have a slightly acid reaction (pH 6.00 to 6.50) returning to neutral with depth.[8]

The amount of humus in arctic gley soils on Wrangel Island is very considerable but its distribution is uneven. In horizon A_1 it varies between 3.29 and 10.48% and quickly decreases with depth to 1.18 to 2.5% at 20 to 30 cm.

Data from the particle-size analyses show that removal of the fine clay fraction from the upper horizons of the arctic gley soils of Wrangel Island evidently does not take place.

The arctic gley soils of Wrangel Island have a relatively low content of assimilated nitrogen and phosphorus compounds. The surface horizon (0 to 5 cm.) contains 0.47 mg. of nitrogen per 100 gm. of soil. The amount of phosphorus in the surface horizons varies from 6 to 25 milligrams per 100 grams of soil.

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[8] The time when Yashina took these samples is not shown.

In the fine-textured clay-loam arctic gley soils of Wrangel Island there appear signs of thixotropy which is most clearly expressed in the tundra gley soils of the subarctic.

The formation of arctic gley and polygonal soils may be complicated and they may even be replaced by bog soils. The arctic gley soils of tracts where mounds and polygons have been formed with a negligible amount of snow cover may be denuded of continuous and even of occasional plant cover. Snow corrasion destroys not only the vegetation but also the surface horizons of the soil; as a result a gley horizon may emerge to the surface of a denuded mound.

The arctic gley-sod soils of Wrangel Island have prominent humus and gley horizons and, although not always, an illuvial horizon. Their thickness is subject to sharp fluctuations depending on their position in the locality and their moisture conditions. On Wrangel Island these soils occupy an extremely small area under excessively moist tracts in regions of the arctic polygonal desert. Usually these tracts represent the bottoms of very small depressions on watershed areas of the piedmont portions of slanting littoral plains and on low terraces in the valleys of large rivers.

As an example of the profile of an arctic gley-sod soil we present our study of a section of the surface of a second flood-plain terrace on the left bank of the Somnitel'naya ("Doubtful") river 200 m. below the brow of its cut and 800 m. from the sea.

Section 1. An even, completely flat surface of a terrace inclined slightly toward the sea with a ragged cover of lichens and grasses (60 to 70%). Surface areas 0.4 × 0.8 m. of the lower 7 to 10 cm. of the plano–convex mounds have been stripped revealing small (1 to 7 cm. in diameter) well–rounded pebbles with a small admixture of coarse sand. The vegetation is composed of bushy lichens, 10%; green mosses, 15%; and seed plants, 40% (chiefly *Dryas* spp.). Two layers are formed above the soil: close to the soil there is a very dense layer of lichens, mosses and ground rosettes of seed plants, with flower-bearing shoots rising to 10 to 15 cm.

A_0, 0 to 8 cm.: Dense, fine-textured peaty sod from lichens, mosses, and the leaves of seed plants.

A_1, 2 to 12 cm.: Brown-cinnamon, fresh sandy loam with an admixture of gravel and pebbles, small granules, fine–grained, compact. No inclusions or new formations. The mass of small roots fastens the granules together in larger peds and clumps one to five cm. in diameter. No fauna seen. Clearly demarcated from the following layer.

B, 12 to 12(37) cm.: Cinnamon-brown, moist sandy loam with a large amount of pebbles. Unstable, easily crumbled platelike structure. In their original stratum the small plates, three to five mm. in diameter, were not visible to the naked eye. Dense, somewhat porous, without inclusions or new formations. In the upper horizons there were streaks, brown-cinnamon in color and 10 to 12 cm. long. The horizon was penetrated by a small number of roots, some of them dead. No peds present, no fauna, boundary clear.

12 to 26(42) cm.: Stony (gravel and pebbles up to five to seven cm. in diameter) with a very small amount of fine soil, fresh, blue or dark-blue when moist and ash-gray when dry, structureless, porous, without inclusions or new formations, and with occasional small plant rootlets.

Typical arctic gley soils are formed under the vegetation of the polygonal mossy deserts with increased moisture (the "oncophoric moss deserts" of B. N. Gorodkov [2]) between mounds on the slopes and in the bottoms of saucer-like depressions and defiles on the central and littoral parts of the littoral plains, and in depressions near the slopes of terraced plains of large rivers. These soil profiles have prominent peat and gley horizons and the latter have inherent thixotropic properties (5, p. 56).

As an example of typical arctic gley soils we will give our description of a section from a location near the second flood-plain terrace at the foot of a flat slope of the right bank of the Tundra river 4 km. north of Tundra mountain:

Section 3. From a depression in a terrace 50 m. south of the source of soil section 2. Microrelief: mounds convex up to 16 cm. with a diameter up to one meter bare in the center. Sodded over 70% of the total surface with a vegetational cover of three layers: on the soil, lichens and moss up to 2 cm. in height (crustaceous and fruticose lichens, *Thamnolia vermicularis* and *Cladonia* spp.); herbaceous-grassy mixture, predominantly sedges, 13 to 16 cm. high, and undergrowth up to 20 cm. high.

A_0, 0 to 2 cm.: Mossy-grassy peat, half-rotted plant remains, wet.

A_1, 2 to 3 cm.: Brown, wet clay loam containing very fine particles, fine pores, solidified, without inclusions or new formations. Root and rootstock mass turned to peat at the upper boundary. Fauna not seen, border sharp.

G, 3 to 46 cm.: Gray light-blue with yellow horizontal streaks, wet, clay loam, containing very fine particles, fine pores, no inclusions or fauna. New formations in the shape of thin layers and tubes. Layer penetrated by a small quantity of roots, full of cracks. Clay suspension has permeated along cracks 0.3 to 3.6 cm. long. Plant roots few extending down to 5 to 7 cm. above the frost. Below 46 cm., ice. Shaking the soil when digging it up caused it to take on a quicksand-like consistency.

The bog soils of Wrangel Island are represented by thin, poorly developed soils of the bottoms of mossy bogs of the shore portions of the inclined littoral plains. A characteristic trait of their southern analogs—a peat horizon—is represented here in rudimentary form. It is 2 to 5 cm. thick. These soils are distributed in saucer-like depressions, defiles, pre–terraces and other depressions of plains and valleys of large rivers under continuous peat-moss cover. There is no microrelief. A description of a soil section of one such moss bog was given by Gorodkov (1).

From a flat, waterlogged depression 5 km. south of the Krasnyi Flag river:

A_0, 0 to 1 cm.: Moss-herb sod, dark-brown, somewhat cracked below.

A_1, 1 to 3 cm.: Brown peaty-ocherous, permeated by roots, transition to the next horizon abrupt.

G, 3 to 34 cm.: Light blue-gray with rusty intrusions and spots, viscous heavy clay loam.

The soil is entirely saturated with water which has come down the slopes.

The mountain arctic soils (soils of stone polygons) are formed on the slopes of low to medium-sized mountains under lichen-moss vegetation which has settled in the troughs of the network of hard polygons. They have only a thin (1 to 4 cm.) friable sod which has tended to turn to peat below (horizon A_0 to A_1) and which is immediately underlain by a coarse framework of deluvium and eluvium not externally different from the detritus of the bare spots.

Those processes of formation of mountain arctic soils which develop under snow meadows and under lichen, arctic, and polygonal deserts may be complicated by waterlogging processes under certain favorable conditions—increase in the thickness of the snow cover in connection with development of the microrelief with an increase in the fine soil fraction in the texture of the soil substrate. Under these conditions, mountain arctic peat soils are formed under mossy bogs.

Mountain arctic peaty soils are characteristic only of hypnaceous and hypnaceo-sphagnous bogs of the slopes of hills and mountains with abundant surface moisture. Peaty sod 3 to 4 cm. thick goes over into a layer 10 to 12 cm. thick of brown hypnaceo-sphagnous peat. The peat lies on a mineral substrate (dark-gray, heavy, saturated with water from the clay loam) which shows no signs of gleying. Such a bog was encountered by Gorodkov (1) on a slope of the left bank of the Nasha river plain north of Ushakovskii at an altitude of 70 m. above sea level.

The distribution of soils on Wrangel Island corresponds to a considerable degree with the distribution of vegetation, particularly with respect to their vertical zonality.

Stony rubble is found at altitudes above 350 m. Within this at isolated spots are found arctic deserts and lichen tundras under which are formed mountain arctic and arctic sod soils. They form combinations with beds of detritus. Below, at altitudes of 100 to 350 m., complexes are formed under the arctic deserts of arctic polygonal and arctic sod soils in combinations with mountain arctic soils and mountain arctic peaty soils. On the bottoms of river valleys the complexes of arctic polygonal and arctic sod soils are replaced in the wettest spots (that is, in pre-terrace depressions) by complexes of arctic polygonal and arctic gley soils; in some places these combine with small spots of bog soils. The arctic carbonate soils and the arctic sod illuvial-humic soils are found near highland streams among complexes of arctic polygonal soils and arctic sod soils.

On plains surrounded by mountains, at an altitude of 100 to 120 m., there is the greatest variation of the soil cover. On piedmont tracts of the slopes of littoral plains complexes are formed of arctic sod, arctic gley-sod, and arctic polygonal soils. They are combined with spots of arctic sod illuvial-humic soils and bog soils. On the littoral portions of plains on watersheds, there is predominance by complexes of arctic polygonal, arctic sod, and arctic gley-sod soils, or of arctic polygonal and typical arctic gley soils in combination with arctic gley-sod and bog soils in saucer-like depressions. On broad, low terraces there is wide distribution of arctic sod soils complexed with bog soils. In the highlands in the immediate vicinity of the shore, arctic polygonal soils predominate. On the shore areas of the northern littoral plains, in a narrow belt along lagoons and bays, are found the arctic solonchak soils.

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POLAROGRAPHIC ANALYSIS OF SOILS DETERMINATION OF ADSORPTIVE CAPACITY

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Notwithstanding their great accuracy, the existing methods for the determination of the adsorptive capacity of soils, suggested by K. K. Gedroits (4), Ye. V. Bobko and D. L. Askinazi (1), A. A. Shmuk (9) and others, are quite long, laborious, and in addition require a large expenditure of reagents. For this reason, the development of a rapid and still sufficiently accurate method for the determination of the adsorptive capacity of soils is of interest. In the solution of this problem, it seemed to us that it would be appropriate to use the polarographic method, which has a number of advantages: high sensitivity, objectivity in the results, good reproducibility, and rapidity of completion.

The polarographic method has found some application in the analysis of soils at the present time. Thus, D. P. Malyuga (6) has determined copper, cadmium, nickel, zinc and cobalt in soils; I. V. Komar (5) and L. Mainzhausen (14) have determined total potassium and sodium; S. I. Sinyakova has developed a method for the determination of lead, cadmium and zinc; P. Stout (17), J. Reed and R. Cummings (16) have also determined zinc in soils; M. Shikata (18) has determined copper; P. A. Vlasyuk and E. S. Kosmatyi (3) have determined iron and manganese.

For this work, we prepared standard solutions of barium and nickel chlorides from analytical grade preparations after preliminary recrystallization. The concentrations were checked gravimetrically. The polarogram was obtained on an M-8 visual polarograph from Gorky University. The galvanometer had the following characteristics: sensitivity, -0.71×10^{-9}A; internal resistance, 2000 Ohms; critical resistance, 5300 Ohms; period of oscillation (length of a cycle), 14 seconds.

Barium Chloride Method. The polarographic method makes it possible to determine substances in concentrations of the order of 10^{-5} to 10^{-6} grams per mole per liter. The high sensitivity of the polarographic method makes possible a decrease in the amount of the soil sample required for analysis to 0.5 to 1.0 g. The small amount of the sample necessitates special care in the preparation of the soil for analysis and in the taking of a representative sample. The soil should be well pulverized and carefully screened through a sieve with a mesh on not less than 1 mm. A one gram sample is weighed on an analytical balance and transferred to a glass funnel with a fritted filter. A glass stopcock is attached to the end of the glass funnel by a rubber tube.

With the stopcock closed, the soil sample on the filter is treated with a small volume of a 1 N solution of barium chloride. After 3 to 5 minutes, the stopcock is opened and the barium chloride solution is completely drained off after it has interacted with the soil. The stopcock is then closed and this operation is repeated. As shown by our work, the soil becomes completely saturated with barium chloride after 12 to 15 times. No calcium ions are found in the filtrate after such treatment. The barium chloride adsorbed on the soil is washed off with distilled water in the same funnel until a negative test for chloride ion is obtained. The funnel together with the washed soil is then placed in the neck of a 100 ml. volumetric flask and the soil is treated with 1N hydrochloric acid in the above manner until 60 to 70 ml. of filtrate has been collected. The hydrochloric acid extract which is obtained is neutralized with calcium oxide until a distinctly alkaline reaction is obtained and, after cooling, the solution is diluted to the mark with water.

A small 40 to 50 ml. flask which is closed with a 3-holed stopper serves as a polarographic cell. The first opening is for the capillary of the mercury electrode, the second for the lead to the anode (a layer of mercury on the bottom of the cell), and the third for the tube through which hydrogen from a Kipp generator is led after preliminary purification by a solution of sodium hydroxide, mercuric chloride and potassium permanganate. Twenty milliliters of soil extract is added to the polarographic cell with a pipette and a stream of hydrogen is led through it for 5 minutes in order to remove the dissolved oxygen. Calcium chloride, formed as a result of the neutralization of the hydrochloric acid by calcium

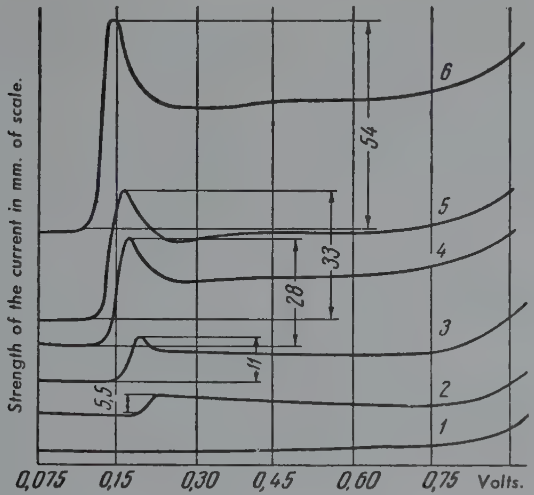

FIG. 3—Anodic curves for Mn^{++} in ammonium medium. 1—Background: a 1N solution of NH_4Cl containing 0.2N NH_4OH. Mn concentration; 2—0.9×10^{-5}; 3—1.8×10^{-4}; 4—4.5×10^{-4}; 5—5.4×10^{-4}; 6—9×10^{-4} moles per liter. The anode is a Pt needle 20 mm. long and 0.3 mm. in diameter.

oxide, serves as a background. The results are computed by the method of additions. In order to do this, after a polarogram has been taken, a definite volume of a standard solution of 0.1N barium chloride is introduced into the solution under investigation from a microburette and a second polarogram is taken under exactly the same conditions. The concentration in the soil extract is calculated from the increase in the curve due to the addition of the standard solution.

The curves for the oxidation of Mn^{++} on a platinum electrode (Fig. 3) have sharp peaks. They are produced by the fact that the rate of increase of the applied voltage is greater than the rate of formation of the diffusion layer. The height of the peaks is found to be proportional to the concentration of the oxidized ions (see Figs. 3–4).

We have also obtained a series of polarograms (Fig. 5) in solutions buffered at various pH values. The oxidation potential and the E½ are displaced by a change in the pH. An increase in both of these values (pH and concentration of manganese ions) displaces the oxidation potential and the E½ in the less positive direction. We used the anodic curves of manganese in alkaline ammonia medium for the quantitative determination of the available, exchangeable and water soluble forms of manganese in the soil. Twelve samples of various soils were taken for investigation.

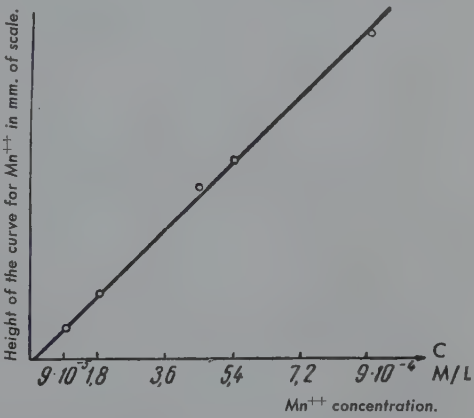

FIG. 4—The effect on the height of the curve for Mn^{++} ions and their concentration in the solution.

Determination of Available Manganese. Ten grams of air-dried soil was agitated for 30 minutes on a rotary shaker with 100 ml. of 0.5N sulfuric acid, after which the suspension obtained was heated for another 30 minutes on a boiling water bath (1). Twenty milliliters of the cooled

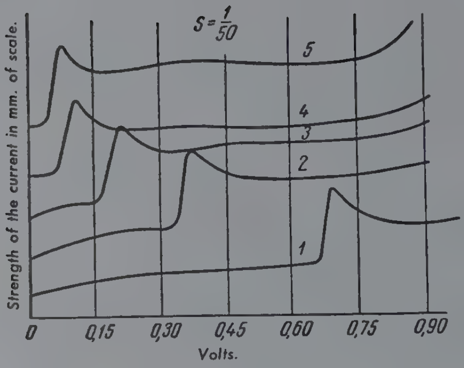

FIG. 5—Curves for Mn^{++} in buffered solutions. The $MnSO_4$ concentration = 9 × 10^{-4} moles per liter. 1—pH = 5.6; E½ = +0.667 v.; 2—pH = 7.5; E½ = +0.352 v.; 3—pH = 8.5; E½ = +0.154 v.; 4—pH = 9.0; E½ = +0.090 v.; 5—pH = 9.5; E½ = 0.060 v. The anode is a platinum needle 8 mm. long.

filtrate was transferred to a 50 ml. volumetric flask and diluted to the mark. With a pipette, 25 ml. of this solution was transferred from the volumetric flask to the electrolyzer. After the preliminary addition of 1–2 drops of alcoholic phenolphthalein solution and a few drops of concentrated ammonia so that the solution became colored (accompanied by the precipitation of an insignificant amount of sesquioxides), polarography was carried out with S = 1/50 to 1/10, depending on the Mn^{++} concentration. After taking the Mn^{++} curve, the platinum electrode was washed off with hot sulfuric acid (1:1) and then with distilled water. One drop of an exactly decimolar $MnSO_4 \cdot 5H_2O$ solution, containing 2.2 × 10^{-4} g. of manganese, was then added to the solution and the polarogram was taken again. The quantity of Mn^{++} in the solution being analyzed and in 100 g. of soil was calculated from the increase in the curve (Fig. 6). Parallel determinations gave exactly the same results.

Determination of Exchangeable (Adsorbed) Manganese. Solutions for the determination of adsorbed manganese in the soil were prepared by the methods used by the majority of investigators, involving its displacement from the soil by the ammonium ion.

A 20 g. sample was added to 50 ml. of 1N ammonium sulfate. After 24 hours, the suspension was agitated for one hour on a rotary shaker. With a pipette, 25 ml. of the filtrate was transferred into the elecrolyzer, 1 to 2 drops of alcoholic phenolphthalein solution and the same amount of concentrated ammonia were added (the solution becoming colored with no observable precipitate formation), and polarography was carried out as in the determination of available manganese (Fig. 7).

Determination of Water-soluble Manganese. The amount of water-soluble manganese in the soil is in the range of some ten-thousandths of a percent. We were unable to obtain waves for the oxidation of Mn^{++} on a 25 mm. stationary electrode. Upon increasing the sensitivity of the galvanometer to ⅕ and ½, a significant residual current was observed which masked the beginning of the manganese wave. For this reason we used a modified polarograph whose essential characteristic is the production of a curve which is a derivative of the usual one. Differentiation of the curve is accomplished electrically with the aid of a condenser and resistance introduced into the galvanometer circuit (7, 10, 11, 12, 14). In contrast to the usual case, the modified curve has no residual current, making possible the use of the high sensitivity range. In order to increase the height of the derived peaks, we used a rotating spiral platinum electrode 25 mm. long and 0.3 mm. in diameter. Rotation, at 60 revolutions per minute, was produced by a Warren motor.

Extraction of the water-soluble compounds of manganese was accomplished by shaking up a 20 g. sample of soil with 100 ml. of water for one hour. Twenty-five milliliters of the filtrate was drawn off into the cell which served as the electrolyzer. Approximately 0.5 g. of dry c.p. ammonium chloride, 1 or 2 drops of phenolphthalein, and 1 or 2 drops of a concentrated ammonia solution were then added (resulting in the appearance of a color but no precipitation) and the solution was polarographed at sensitivities of ⅕ and ½ (Fig. 8). The electrode was then washed off as described previously. One drop of a standard solution containing 2.2 × 10^{-5} g. of Mn^{++} was then added and the solution was polarographed again. As before, the calculations were made on the basis of the percentage increase in the wave per unit weight of absolutely dry substance. The data of the polarographic analysis were verified by the colorimetric persulfate method as modified by P. A. Vlasyuk and V. Ya. Gornaya (2). The results of the analyses are reproduced in Table 2.

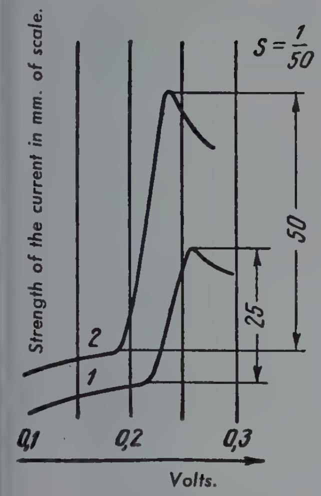

FIG. 6

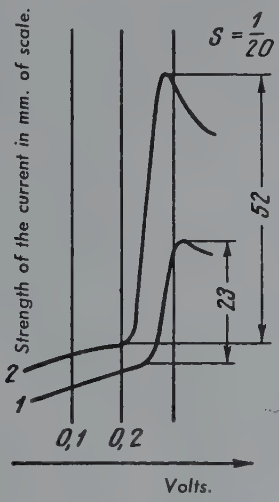

FIG. 7

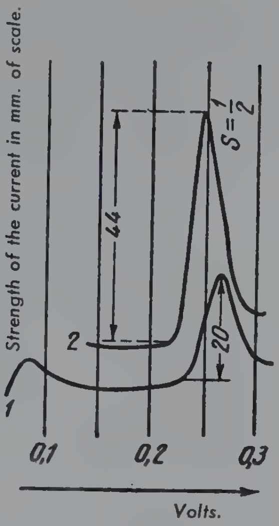

FIG. 8

FIG. 6—Waves for available manganese. 1—Polarogram of Mn^{++} in a sulfuric acid extract of soil No. 5; 2—the same, after the addition of 2.2×10^{-4} g. of Mn^{++}. The anode is a spiral Pt wire 25 mm. long.

FIG. 7—Waves for exchangeable (adsorbed) manganese. 1—Polarogram of exchangeable Mn^{++} in an extract of soil No. 24; 2—the same, after the addition of 2.2×10^{-4} g. of Mn^{++}. The anode is a spiral Pt wire 25 mm. long.

FIG. 8—Derived peaks for water-soluble manganese. 1—Derived peak for Mn^{++} in an aqueous extract of soil No. 9; 2—the same, after the addition of 2.2×10^{-5} g. of Mn^{++}. The anode is a spiral Pt wire 25 mm. long.

The quantity of available manganese that we found in the soils of the various regions agrees with the data published by the Ministry of Agriculture, Ukranian Soviet Socialist Republic, in the form of a map showing the content of available manganese (in percent) in the soils of the Ukrainian SSR. The map was prepared in 1948 by the Ukrainian Scientific Research Institute of Socialist Agriculture.

In Figure 1 are shown polarograms of barium chloride solutions on a background of calcium chloride. It is apparent from the figure that it is possible to obtain a perfectly distinct wave for barium chloride on a background of calcium chloride. The half-wave potential for barium equals 1.83 volts with respect to the mercury anode at the bottom of the cell. The height of the wave is 18 mm. at S = 1/20. After the addition of 0.15 ml. of a standard 0.1N barium chloride solution to 20 ml. of the extract, the height of the wave is increased to 26 mm.

The concentration of the soil extract can be determined by the following formula:

$$C_1 = \frac{i_1 V_1 C \text{ stand.}}{\Delta i (V + V_1) + i_1 V_1}$$

where C_1 is the concentration of the solution being examined; i_1 is the initial diffusion current; Δi is

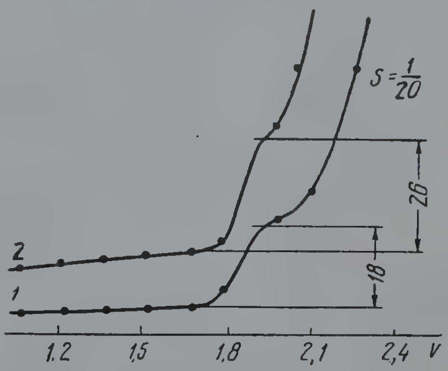

FIG. 1—Polarogram of barium on a background of $CaCl_2$. 1—Soil extract; 2—the same after the addition of 0.15 ml. of a 0.1N $BaCl_2$ solution.

the increase in the diffusion current caused by the addition of the standard solution; V is the initial volume of the solution being examined; V_1 is the volume of standard barium chloride solution added; and $C_{\text{stand.}}$ is the concentration of the standard solution. Substituting our data in equation (1), we obtain:

$$C_1 = \frac{18 \times 0.15 \times 0.1}{8(20 + 0.15) + 18 \times 0.15}$$

$$= 0.00164 \text{ g.e./l. or } 1.64 \text{ me./l. of barium ions}$$

The calculated concentration corresponds to the number of milligram equivalents per liter. In 100 ml. of soil extract, corresponding to 1 g. of soil, there will be 0.164 me. Therefore, the absorptive capacity per 100 g. of soil equals 16.4 me.

The values for the adsorptive capacity obtained by the polarographic method agreed with the data obtained by the method of Bobko and Askinazi. The average values from a series of experiments are presented in Table 1.

Nickel Chloride Method. In 1929, Shmuk (9) suggested that small samples of soil could be treated with nickel salts, after which the nickel displaced from the soil could be titrated with potassium cyanide. The method did not find wide application because it required working with a strong poison. We have therefore thought it worthwhile to suggest a polarographic treatment of the Shmuk method.

A 1 g. sample of thoroughly pulverized and sifted soil was treated 10 to 12 times with a 0.5N solution of nickel chloride in the manner described above. The sample was then washed with water until the test for nickel was negative (as tested with dimethylglyoxime in the presence of sodium acetate). The adsorbed nickel was then extracted with 0.5N hydrochloric acid. The filtrate was collected in a 100 ml. volumetric flask, 25% ammonia added until the reaction became alkaline, and the solution diluted to the mark with water.

For the polarographic determination of nickel, 10 ml. of solution was removed from the volumetric flask by means of a pipette and transferred to a polarographic cell, after which hydrogen was passed in and the polarogram was taken. Ammonium chloride, which was formed as the result of the neutralization of hydrochloric acid by ammonia, served as the background. In these experiments, the anode was an external saturated calomel electrode, connected to the polarographic cell by means of a low-resistance agar siphon containing potassium chloride. In order to depress the maxima obtained on the curve, 1 ml. of 0.5% gelatin was added to the solution.

According to the data in the literature, nickel, in an ammoniacal medium in the presence of NH_4Cl and gelatin, forms good waves with a half-wave potential of about 1 volt (9).

A polarogram for nickel from a soil extract on a background of ammonium chloride and ammonia (1) is shown in Figure 2. The height of the wave is 33 mm. After the addition of 1 ml. of a standard 0.01N nickel chloride solution (polarogram 2), the height of the wave is seen to increase to 46 mm.

The calculated values for the adsorptive capacity of various types of soil are presented in Table 1.

Looking at the table, it is possible to conclude that the polarographic method gives results which

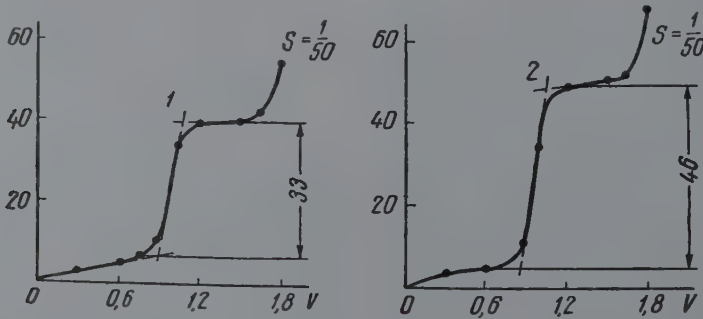

FIG. 2—Polarogram of nickel on a background of NH_4Cl. 1—Soil extract; 2—the same after the addition of 1 ml. of a 0.01N $NiCl_2$ solution.

agree with the chemical method of Bobko and Askinazi, but the former is faster.

Determination of Manganese in Soils. The polarographic determination of manganese in soil extracts is interfered with by a number of cations (namely Fe^{+++}, Fe^{++}, Al^{+++}, Zn^{++} and H^{+}) whose reduction on the dropping mercury electrode takes place at potentials close to the potential for the production of manganese. In the present work, the basis for the polarographic determination was the anodic waves of manganese which were first obtained by N. I. Belinskaya on a platinum electrode in ammoniacal medium.

The work was carried out on the automatic polarograph constructed by the Institute of Structural Mechanics, Academy of Sciences, Ukrainian SSR. The galvanometer used was the mirror galvanometer of the Leningrad Institute for Physical Instrument Design, with the following characteristics: sensitivity $= 1.6 \times 10^{9}$ a.; internal resistance, 333 ohms; critical resistance, 967 ohms; period of oscillation of the galvanometer, 6.1 seconds. The rate of application of the external EMF amounted to 0.00625 to 0.00417 volts per second.

The anode was a platinum wire with a cross-section of 0.3 to 0.5 mm. in diameter and 8, 20,

TABLE 1

Determination of the adsorptive capacity of soils.

Names of the soils	Adsorptive capacity in me./100 g. soil		
	Chemical method of Bobko and Askinazi	Polarographic method	
		By Ba^{++} extraction	By Ni^{++a} extraction
Podzolized chernozem Drogobych region	15.90	16.50	15.93
Dark-gray podzolized soil Zhitomir region	18.30	—	27.8
Thick chernozem Zhitomir region	15.20	—	15.46
Thin, fine-textured clay loam chernozem Moldavian ASSR	40.00	—	39.8

[a] The data obtained by Ni^{++} extraction are the averages of three observations.

TABLE 2

The determination of manganese in soil extracts by polarographic and colorimetric methods.

Sample No. of soil	Depth in cm.	Polarographic method Mn^{++} in %			Colorimetric method Mn^{++} in %	
		Available	Adsorbed	Water-soluble	Available	Adsorbed
1. Gray podzolized. Zhitomir region, Berdichev district.	30	0.023	0.0028	not detected	0.031	0.0027
2. Sod, weakly podzolized. Zhitomir region, Dzerzhinsk district.	30	0.032	0.0032	0.0002	0.029	0.0030
3. Thick leached chernozems. Zhitomir region, Dzerzhinsk district.	30	0.034	0.0035	not measured	0.031	not measured
4. Low-humus meadow soil. Khmel'nitsk region, Polonsk district.	45	0.021	0.0022	not detected	0.021	0.0020
5. Sod, weakly podzolized. Khmel'nitsk region, Polonsk district.	20	0.022	0.0022	0.0006	0.026	0.0021
6. Gray forest soil. Ternopol region, Berezhansk district.	30	0.028	0.0039	0.0001	0.031	0.0036
7. Ordinary thin chernozem. Kishinev region, Leovsk district.	30	0.038	0.0014	not detected	0.040	0.0012
8. Gray forest soil. Drogobych region, Novo-Strelishchansk district.	30	0.062	0.0062	0.0009	0.063	0.0060
9. Light-gray forest soil. L'vov region, Kam.-Bug district.	30	0.030	0.0025	0.0004	0.029	0.0024
10. Podzolized chernozem. L'vov region, N.-Yarychev district.	30	0.042	0.0019	not detected	0.041	0.0017
11. Dark-gray forest soil. Stanislav region, Rogozhinsk district.	30	0.047	0.0029	not measured	0.049	0.0028
12. Sod-gley in a complex with meadow soil. Stanislav region, Otynyansk district.	30	0.043	0.0010	0.0004	0.045	0.0013

or 25 mm. long in the form of a needle, loop, or spiral. In all cases, the cathode was a saturated calomel electrode, which was connected to the solution under investigation by a low-resistance agar-agar switch. Before each polarogram, the anode was either depolarized by short-circuiting the electrodes briefly, or washed with hot sulfuric acid (1:1) and then with distilled water. In this way, all the polarograms were taken under uniform conditions. The current became zero when a potential of approximately 0.1 volts was applied to the cell.

During the polarography of Mn^{++} on a background of 1 M solutions of ammonium chloride, nitrate, sulfate and oxalate, containing 0.17 to 0.25 N NH_4OH, we detected the deposition of a brown precipitate on the platinum anode. This precipitate was not dissolved by nitric acid. When this precipitate had accumulated sufficiently and was treated with concentrated hydrochloric acid, chlorine was produced; consequently we suggest that manganese is oxidized to MnO_2 in alkaline ammonia medium.

Conclusions

1. A rapid polarographic method for the determination of the adsorptive capacity of soil is proposed which gives sufficiently accurate results, agreeing closely with the results of the chemical method of Bobko and Askinazi.

2. The adsorptive capacity of various soils is determined by the polarographic method, involving extraction of the adsorbed cations by the salts of barium, nickel and lead.

3. The wave for the oxidation of Mn^{++} was first detected on a platinum micro-electrode in alkaline ammonia medium. The anodic oxidation of manganese is used for its quantitative determination in soils.

4. The proposed method for the determination of manganese has the following advantages: a) the rapidity of the analysis (determination of the manganese from a soil extract after preparation of the solution requires two to three minutes); b) neither Fe^{+++}, Al^{+++}, Fe^{++} or H^+, nor the chloride ion or the organic substances of the soil interfere with the anodic oxidation of Mn^{++} in ammonium medium; c) both the objective determinations and the calculations are based on the readings of a galvanometer; d) the consumption of an insignificant quantity of simple reagents.

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A MODIFIED KJELDAHL METHOD FOR THE DETERMINATION OF TOTAL NITROGEN

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THE widely-used Kjeldahl method for the determination of nitrogen gives reliable and consistent results when it is applied to the analysis of soils. However, the use of this method for large-scale analytical determinations is accompanied by a series of consequent difficulties. Among these must be included: 1. The duration of the operations involving combustion of the soil with concentrated sulfuric acid and the elimination of ammonia after the addition of strong alkali. 2. The absence of a sufficient number of hard-glass flasks for the combustion (Kjeldahl flasks). 3. The large expenditure of sodium hydroxide and concentrated sulfuric acid. 4. The obligatory presence of a separate table for the setting up of the distillation apparatus, this being especially difficult for small laboratories. 5. The necessity of a permanent control for the elimination of ammonia.

In connection with these difficulties, the question arose of changing the Kjeldahl method to make the technical performance of the analyses easier while retaining the overall accuracy of the determination.

The determination of nitrogen in the soil by the Kjeldahl method (1) is based on the fact that when a soil sample is boiled with concentrated sulfuric acid, the soil nitrogen, being found primarily in organic compounds, is transformed into ammonia and reacts with the sulfuric acid to form ammonium sulfate. The latter is decomposed upon the addition of strong alkali; the ammonia produced by this is distilled off with steam and determined in the distillate by titration or colorimetry. Several variations of the Kjeldahl method exist, both in relation to the method of combustion of the organic matter of the soil (2, 3, 4) and with respect to the quantitative determination of the ammonia (7, 8).

In the laboratory of the Department of Soil Geography of the soil biology faculty of Moscow State University, a procedure was worked out which combines a combustion from the I. F. Golubev method of determining total nitrogen with the subsequent quantitative determination of the ammonia according to the method first suggested by O. Conway and A. Byrne for the determination of nitrogen in the blood, based on the principle of natural diffusion of gaseous substances, without the use of distillation.

Steam distillation of the ammonia, which is unavoidable in all methods for the determination of total nitrogen (1, 2, 3, 4), was replaced by trapping the ammonia in sulfuric acid in Conway dishes (without distillation) after the addition of sodium hydroxide. The glass Conway dish is illustrated in the figure. Inside it there is a cylinder which does not reach the level of the edges of the dish and thus forms an essentially isolated vessel. The edges of the dish are bent back one centimeter and polished. The dish is well covered by a polished glass plate which is greased during a determination by a mixture of vaseline with wax or lanolin. According to Conway, the use of this dish is based on the principle that the ammonia will diffuse from the large vessel (the outer ring of the dish) into the container of acid, represented here by the small vessel (the inner cylinder).

The internal diameter of a Conway dish is 7 to 8 cm., its height 2.5 cm. and its volume 25 to 30 ml. The diameter of the inner vessel is 3 cm., its height 2 cm., and its volume 6 to 8 ml.[1]

The glass dishes can be replaced by dishes made of paraffin (5). These can be used several times, after which they must be recast. After diffusion, the ammonia is determined by titration as in the Kjeldahl method.

The combination of a Golubev combustion of the organic matter of the soil and a quantitative determination of the ammonia after diffusion by the method of Conway and Byrne makes possible the proposal of the following method for the determination of total nitrogen in soils.

1. Combustion of Soil by I. F. Golubev Method. A weighed soil sample of 0.3 to 2 g., depending on the humus content, is placed in a tapered flask having a volume of 100 to 150 ml.

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[1] Conway dishes can be manufactured in glass-blowing shops. Molybdenum glass is usually used in their manufacture.

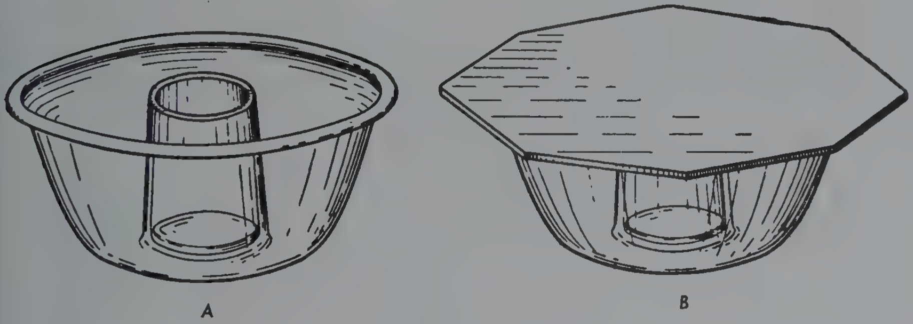

FIG. 1—A Conway dish. a—open; b—with cover.

and mixed with 5 ml. of concentrated sulfuric acid, a knife-point of mercuric oxide or powdered selenium being added as a catalyst. The addition of catalysts is optional; boiling with H_2SO_4 can also be carried out in their absence, simply increasing the time of boiling to 15 to 20 minutes if necessary. The flask is covered by a funnel having a curved spout on the side and is heated to boiling on a grid in an exhaust hood. Gentle boiling is continued for 10 minutes. At the end of the boiling, the flask is taken off the grid and, after slight cooling, 30 ml. of water and 20 ml. of 0.5 N $KMnO_4$ are carefully added, dropwise and with stirring. The flask is again placed over the flame (on the grid) and boiled for 10 minutes. After this, the combustion can be considered finished. In order to determine the completeness of the combustion, a saturated solution of oxalic acid is carefully added to the flask through a funnel until the precipitated oxides of manganese are completely redissolved. After complete combustion, the solution should be clear and colorless, sometimes with a yellowish tint. The mineral portion of the soil—the "white sand"—remains on the bottom of the flask. The whiteness of this residue is another indication of the completeness of the combustion operation. In those cases where the soil is not combusted to completion (this is usually rare and is clearly visible after the addition of oxalic acid), the analysis must be repeated, decreasing the sample.

2. Quantitative Determination of Ammonia Without Distillation. After combustion, the contents of the flask is transferred to a 100 ml. volumetric flask, water is added up to the mark, and the flask is shaken carefully and allowed to stand until the solution clears. Ten ml. of this solution is taken out with a pipette and placed in the large outer chamber of a Conway dish, 2 or 3 ml. of 0.02 N H_2SO_4 (concentration determined exactly) being added to the inner chamber from a microburette. One or two drops of Tashir's indicator (a mixture of methyl red and methylene blue) are added to both chambers. The indicator solution is prepared in the following way:

Stock solution: Ten ml. of a 0.1% alcoholic solution of methylene blue is added to 40 ml. of a 0.1% alcoholic solution of methyl red.

Working solution: One volume of alcohol and two volumes of water are added to one volume of the stock solution, after which the mixture is allowed to stand for awhile. This indicator is one of the most sensitive with respect to an abrupt change in color. It gives a reddish-violet color in acid medium and a bright-green color in alkaline medium. The change is very abrupt, the pH at the point of change being 5.2 to 5.6.

After addition of the indicator to the Conway dish, the cover is put on in such a way that only a small opening remains, through which 4 to 8 ml. of a 40% NaOH solution is added; the dish is then hermetically sealed by means of the cover and carefully agitated. The apparatus is left like this for 6 to 8 hours at room temperature (preferably overnight) or for 2 to 3 hours in a constant temperature room at 37°C[2]. At the end of the diffusion process, the residual acid is titrated directly in the Conway dish by means of alkali at the same concentration from a microburette.

The end of the titration is accompanied by an abrupt change in the color of the indicator from

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[2] In order to accomplish the diffusion of the ammonia from the alkaline fluid into the flask with acid.

TABLE 1

Results of the comparative determination of total nitrogen in sod–podzolic and flood-plain soils of Ryazan region.

Soil designation	Depth of sample, cm.	% total nitrogen (Kjeldahl)	% total nitrogen combined method
Meadow, clay loam, gleyed	A′ 4–14	0.17	0.18
	A_1'' 14–24	0.16	0.16
	B 40–50	0.15	0.13
Sod-thick-podzolic, coarse-textured clay loam, on sand	A_{sod} 0–4	0.24	0.24
	A_1 5–15	0.14	0.15
	A_2 20–30	0.06	0.09
Sod-meadow, coarse-textured clay loam, gleyed, on sand	A_1 0–10	0.32	0.36
	B_1 25–35	0.12	0.14
	B_2 60–70	0.09	0.12
Sod-weakly-podzolic, coarse-textured clay loam, arable	A_{plow} 0–16	0.08	0.09
	A_2B 16–28	0.05	0.04
	B_1 35–45	0.03	0.05
	B_2 60–70	0.03	0.03
Sod-medium-podzolic, sandy loam, arable	A_{plow} 5–15	0.11	0.14
	A_2 20–28	0.06	0.05
	A_2B 30–40	0.07	0.05
	B 50–60	0.09	0.07
Sod-meadow, clay loam, on buried podzolic	A_{sod} 0–4	0.48	0.44
	A_1' 4–14	0.29	0.32
	A_1'' 14–24	0.30	0.28
	B_1' 30–40	0.21	0.25
	A_2 50–60	0.11	0.13
	B 70–80	0.14	0.28
Sod-weakly-developed coarse-textured clay loam	A_{sod} 0–6	0.10	0.08
	A_1 10–20	0.02	0.03
	layer 35–45	0.11	0.12

lilac-red in the presence of acid to green in the presence of a very small excess of alkali.

A control determination is carried out in parallel under analogous conditions.

Acid taken into flask-2 ml. of 0.02 N	Acid combined with ammonia-determined by difference	Residual acid not combined with ammonia–determined in the analysis

Sample calculation: 1.95 ml. of 0.02 N NaOH was used up for the titration of the control sample (2 ml. of 0.02 N H_2SO_4), while 1.05 ml. was used for titrating the experimental sample; the quantity of acid combined with ammonia in the experimental sample was therefore 1.95 minus 1.05 or 0.90 ml.

1 ml. 0.02 N H_2SO_4 = 0.28 mg. of nitrogen

Ten ml. of solution from a total volume of 100 ml., containing a 0.6 g. sample was taken for the determination. Therefore, the nitrogen content in percentage is:

$$\frac{0.90 \times 0.28 \times 100}{0.06} = 0.42\,\%$$

Nitrogen determinations were carried out by the above method on various samples of sod-podzolic and meadow soils from Ryazan region and on samples of chernozem from Altai territory, the Voroshilovgrad region. The nitrogen was simultaneously determined by the Kjeldahl method in these same samples. The data obtained are presented in Tables 1 and 2.

The data from the analyses show good agreement between the results of the determination of total nitrogen by the method described above and by the Kjeldahl method. The discrepancy between the data does not exceed the limits of accuracy of the method; the absolute error is not large, amounting to a few hundredths of a percent. A comparison of the obtained values also indicates that, in the determination of total nitrogen by the method described, there is no tendency to arrive at consistently lower or higher values than those obtained by the Kjeldahl method.

The accuracy of the quantitative determination of nitrogen by the diffusion method without distillation was also confirmed with the aid of a sample solution of NH_4Cl (the NH_4Cl was twice recrystallized) with a precisely known content of NH_4^+ per milliliter (Table 3). As is apparent from Table 3, the absorption of ammonia reached 98.8, 99.8, and 100%, which indicates the accuracy of the suggested method.

In 1955, an article was published by Bremner and Shaw (9), entitled "Determination of ammonia and nitrates in soils." In this, the authors give a detailed description of a method for the determination of absorbed ammonia in soils and peats without distillation, in Conway dishes, which is being used by the Rothamstead Experimental Station, as well as for the determination of nitrates in these same dishes by means of their preliminary reduction with titanium sulfate and their subsequent quantitative determination in the form of NH_3. The investigators emphasize that the method has an accuracy which permits the determination of quantities of nitrogen as small as 0.014 mg., and that the completeness

TABLE 2

Results of the comparative determination of total nitrogen in chernozems.

Soil designation	Depth of sample, cm.	% total nitrogen (Kjeldahl)	% total nitrogen combined method
Ordinary fine-textured clay loam chernozem; Altai territory	A_1 0–5	0.39	0.36
	A_1' 10–15	0.43	0.39
	A_1'' 20–25	0.30	0.28
Ordinary thin carbonate chernozem; Altai territory	A_1 0–5	0.27	0.30
	A_1' 20–25	0.24	0.27
	A_1'' 30–35	0.20	0.21
Ordinary medium-textured clay loam chernozem; Voroshilovgrad region	A_1 2–10	0.48	0.51
	A_1' 25–35	0.27	0.29
	A_1'' 42–52	0.22	0.20
Ordinary medium-textured clay loam chernozem; Voroshilovgrad region	A_1 0–10	0.47	0.45
	A_1'' 25–35	0.34	0.31
Ordinary medium-textured clay loam chernozem; Voroshilovgrad region	A' 0–10	0.27	0.24
	A_1'' 27–34	0.30	0.32
Ordinary medium-textured clay loam chernozem; Voroshilovgrad region	A' 0–10	0.33	0.35
	A_1'' 25–35	0.29	0.27
Podzolized clay loam chernozem; Altai territory	A' 0–10	0.52	0.52
	A_1'' 15–25	0.39	0.35
	B_1 30–40	0.20	0.23
Podzolized clay loam chernozem; Altai territory	A_1 0–10	0.71	0.65
	A_1'' 15–25	0.52	0.52
	B_1 30–40	0.31	0.28
Thick, leached, slightly eroded chernozem; Altai territory	A_1 0–10	0.48	0.49
	A_1'' 20–30	0.40	0.38

TABLE 3

Verification of the Conway method on a sample solution of NH_4Cl.

Amount of NH_4Cl in ml.	Content of ammonia in mg.	Content of ammonia in mg., determined by the Conway method	% absorption of the ammonia produced
0.5	0.090	0.089	98.88
1	0.181	0.180	99.45
2	0.362	0.360	99.45
3	0.543	0.545	99.81
4	0.724	0.726	100.27

of absorption of the ammonia produced reaches 99.4 and 99.8% in determinations of ammonia and nitrate nitrogen in sample solutions of NH_4Cl and KNO_3. A series of compounds which hinder the determination of ammonia do not interfere with the completion of the analyses under the given conditions. It is possible to carry out up to 50 determinations simultaneously[3]. Another important detail, according to the authors, is the fact that this method can also be used for the determination of nitrogen in plant materials.

The good agreement between the analytical data obtained by the described method and the results of the determination of nitrogen by the Kjeldahl method (plus the simplicity of the determination in the presence of sufficient accuracy, the elimination of the distillation of ammonia, the economy in the use of reagents, and the positive evaluation of the diffusion method by other investigators) gives us the right to recommend the modified Kjeldahl method described above for the determination of total nitrogen in soils.

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Book Reviews

SCIENTIFIC PUBLICATIONS OF THE N. PUSHKAROV INSTITUTE OF SOIL RESEARCH, BOOK I, 1956, SOFIYA

I. N. Antipov-Karatayev

Ministry of Agriculture. Administration of Agricultural Information and Scientific Research. Scientific Papers of the N. Pushkarov Institute of Soil Research. Book I. Supplementary Vol. XI to the symposium, "Agricultural Thought," 1956.

The volume under review contains the following papers by members of the N. Pushkarov Soil Institute: 1) Yevgenii Tanov, "Nikola Pushkarov and the development of Bulgarian soil science;" 2) Yevgenii Tanov, "A new 1:200,000 medium-scale soil map of the People's Republic of Bulgaria;" 3) Khr. Trashliyev and T. Ovcharova, "Soils of the Karaboaz lowland;" 4) E. Angelov, "Soils of the Danube River region lowlands;" 5) T. Palaveyev and A. Ralchev, "Soils of the Agricultural Labor Cooperative of the village of Maslovo, Sofia region;" 6) A. Ralchev, "Soils along the course of some state forest shelterbelts in the Dobrudja;" 7) V. Naidenov, G. Khinov, A. Ralchev and I. Donchev, "Soils of the Agricultural Labor Cooperative of the village of Grivints, Pleven region."

The paper by Ye. N. Tanov on the new 1:200,000 medium-scale soil map of the People's Republic of Bulgaria sets forth the principles of the genetic classification of Bulgarian soils, as well as the methods of soil surveying and the regular patterns of distribution of various soils in the country, and the contents of the map itself. Appended to the paper is a 1:1,000,000 composite soil map of the People's Republic of Bulgaria in color prepared by Ye. Tanov with the assistance of V. Koinov for the Thracian lowland.

The following two papers (Khr. Trashliyev, T. Ovcharova and Ye. Angelov) on the soils of the Karaboaz lowland and on the soils of the Danube River region lowlands, present diversified material on the nature of the ground water, textural, and chemical makeup and hydrophysical properties of the soils occurring in the areas investigated. Judging from the degree of salinization of the ground water (see Table 2 of the first paper) and the qualitative composition of its salts, as well as from the salinized profile of some of the soils, solonetz soils, too, must be found here. It is to be regretted, however, that the authors of the papers did not touch on the characteristics of the soils studied with respect to their composition in exchangeable cations.

Of great interest are the works of T. Palaveyev and A. Ralchev and of the group of authors (V. Naidenov *et al.*) devoted to a soil survey of the area of two agricultural labor cooperatives on a scale of 1:10,000. The Pushkarov Soil Institute began work in 1952 on the compilation of large-scale soil maps for individual state and cooperative farms. Similar surveys preceded a detailed classification of the soils, including types, subtypes, species, varieties, and variants of soils. The soil units distinguished are characterized in terms of texture, hydrophysical properties, and agricultural chemical indicators. As a result, a large-scale agricultural characterization has been compiled from data on the productivity of various agricultural crops, the kind of agricultural engineering, and the requirements for fertilizers and irrigation. In addition to the soil maps in color, cartographic diagrams on the same scale have been compiled for: 1) the distribution of farm land in the area investigated; 2) the allocation by projects of various crop rotations (field, vegetable, areas near the farm, soil conservation, and so forth); 3) basic tillage systems; and 4) systems of fertilization.

The investigations are accompanied by an adequate quantity of analytical material. The lack of determinations of exchange capacity and of the content of exchangeable cations is conspicuous, and so is the lack of forms of acidity of the leached chernozems—smolnitsa[1], leached cinnamon-brown forest soils, and gray forest soils. It must be supposed that these omissions will be corrected in future works of the Pushkarov Soil Institute.

A. K. Ralchev's paper describes in detail the forest vegetation conditions and properties of the Dobrudja chernozems in which the planting of state forest shelterbelts has been projected. This paper, like all those reviewed above, contains valuable and abundant analytical material.

A welcome must be extended to the beginning of publication of the broad volume of material at the disposal of the Pushkarov Soil Institute of the Bulgarian People's Republic.

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[1] Southern Bulgarian chernozem—Translator.

Chronicle

STATUS AND DEVELOPMENT OF AGRICULTURAL CHEMISTRY IN THE BULGARIAN PEOPLE'S REPUBLIC[1]

A. S. Radov

THE first organized scientific investigations in the fields of agriculture and agricultural chemistry in Bulgaria go back to the beginning of the twentieth century and the founding of the agricultural experiment stations in Sadovo (near the city of Plovdiv), on the model farm in Ruse, and in Sofiya at the Academy of Sciences and the university. At this time were made the first experiments at setting up field experiments with fertilizers to determine the soil nutrient requirements for various agricultural crops. As a result, a network of experimental institutions for the study of the effectiveness of fertilizers grew up and reached broad development after 1944, that is, after establishment of the authority of the people's democratic Fatherland Front. At the present time agricultural chemistry is being successfully developed in all scientific research and experimental institutions of the Bulgarian Academy of Sciences, branch agricultural institutes and agricultural colleges. It is being realized in practice in the broad fields of cooperatives and state farms.

The development of agricultural chemistry was made possible by the creation of the fertilizer industry. In 1951 the mightiest structure in Bulgarian socialism entered the ranks of active undertakings: the Dimitrovgrad Chemical Combine. In 1952 the Chemical Combine began to furnish Bulgarian agriculture with 70,000 to 80,000 metric tons of ammonium nitrate and some urea. At present a factory is being built in Dimitrovgrad for the production of granulated superphosphate. The factory will go onstream at the end of 1957 and will produce 100,000 metric tons of phosphorus fertilizer yearly which the Bulgarians must now import.

The largest scientific institutions which are developing agricultural chemistry in Bulgaria are:

1. The Soil Institute of the Academy of Sciences.
2. The Pushkarov Scientific Research Institute for Soil Science of the Ministry of Agriculture.
3. The Scientific Research Institute for Cotton Raising in the town of Chirpan.
4. The "Maritsa" Scientific Research Institute for Vegetable Raising.
5. The Scientific Research Institute for Tobacco Raising in Plovdiv.
6. The Scientific Research Institute for Agriculture in the town of Knezha.
7. The Departments of Agricultural Chemistry of the Sofiya and Plovdiv State Agricultural Institutes and some others.

There are about 20 institutions in all.

The Soil Institute of the Bulgarian Academy of Sciences is headed by a professor, Academician Stranskii. The Institute has six sections at work including two of independent status, the Soil Museum and the Bozhurishche Experimental Tract in the Sofiya region, the soil of which consists of the typical "Smolnitsa" chernozem.

At the Experimental Tract experiments have been begun in the study of:

1. Forms of nitrogen fertilizers.
2. Fertilizing systems in eight-field crop rotations.
3. Mineral fertilizers (ammonium nitrate, superphosphate and ashes) under tobacco, and Lysenko-type organomineral fertilizers.
4. Bacterial fertilizers under soybeans (begun in 1954). Wide studies are being made at the Institute of azotobacterins on various types of soils with corn, cotton, tobacco and winter wheat crops. It was established that cotton and winter

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[1] From impressions at the time of a scientific mission, 1955–1956.

wheat do not stimulate the development of azotobacters. The favorable development of azotobacters has been observed in the rhizospheres of tobacco and rice roots (2) in "Smolnitsa" soils. They are especially responsive to phosphorus fertilizers, next most sensitive to lime, less to nitrogen, and least to potassium. Most of the soils of Bulgaria react to phosphorus and nitrogen.

The second large institution developing agricultural chemistry in Bulgaria is the Nikolo Pushkarov Scientific Research Institute for Soil Science which is under the Ministry of Agriculture. It was organized in 1948. Its basic investigative work is done on experimental tracts. A part of it is realized on cooperatives and state farms, and a number of the projects are carried out in different regions of the country. Its Section of Agricultural Chemistry is working out five basic problems:

1. The role of organic fertilizers in raising the fertility and improving the structure of "Smolnitsa" soil and gray forest soils. As a part of this problem, experiments are being carried out on different parts of the tracts with the following: a) quantities of manure increasing from 15 to 60 metric tons per hectare; b) organomineral fertilizers in quantities equivalent to these quantities of manure; and c) mineral fertilizers in quantities equivalent to the quantities of manure in the first variation (a).

2. Increasing the effectiveness of phosphorus fertilizers and of Lysenko-type organomineral mixtures on cinnamon-brown and on gray forest soils.

3. Liming natural acid meadows with quantities increasing from 64 to 720 kilograms per hectare of CaO with surface application. High effectiveness of large quantities was revealed.

4. Soil nutrient requirements with sowings of spring grain crops.

5. Study of the quantity of nitrogen fertilizers (urea).

The Division of Soil Chemistry is studying: 1) The chemical properties of soils as related to mapping and improvement for irrigation purposes; and 2) investigation of the forms of phosphorus and potassium in the soils of Bulgaria. Papers by I. Donchev (4) and G. Khinov (18) on the forms of phosphorus in the soil have been published. For the next several years the Division has the problem of studying the content of forms of nitrogen and trace elements phosphate conditions in cinnamon-brown soils and the production of methods applicable t Bulgarian soils for determining the soil conten of humus, phosphorus, nitrogen, acidity, an some other factors.

The Division of Microbiology is studying: 1 bacterial fertilizers on leguminous plants; 2 the effect of organomineral fertilizers on th rhizosphere of root systems; 3) the effect of lim on the microflora of "Smolnitsa"; and 4) micro biological aspects of experiments by other di visions. In addition, this Institute is closely su pervising the methods of all soil and agricultura chemical laboratories of the experimental institutions of the country.

The Departments of Agricultural Chemistry of the Sofiya and Plovdiv Agricultural Institutes have become large centers for work in agricultural chemistry. Organization of the Department of Agricultural Chemistry in the Faculty of Agronomy of the University of Sofiya began in 1923. All the teaching work of the Department has been concentrated on agricultural chemical analysis. Until 1932 "Fertilizers" was taught as a part of the course on "General Agriculture," but then the two were separated into independent courses. This Department was headed by Professor Mikhail Dmitrov Khodzhaev (who died in 1936). The first stage of the scientific work consisted in working out analytical methods and in the study of the chemical composition of tobacco; some questions of the use of fertilizers were studied; and investigations of citric acid were also undertaken. Since 1936, agricultural chemistry has been headed by the Professor, Dr. Tsventan Staikov and Docent Evgenii Levenson.

In 1947 the Sofiya Agricultural Academy was organized on the basis of the Agricultural Faculty which was separated from the University; the same year an independent Department of Agricultural Chemistry was organized in the Bulgarian People's Republic. Professor Staikov and his colleagues of the Department of Agricultural Chemistry have published more than 20 scientific papers. Of these the following papers by Professor Staikov deserve mention: 1. Exchangeable cations of Bulgarian soils (16); 2. The effect of adsorbed calcium and magnesium on soil acidity; 3. The role of calcium in soil fertility; 4. "Free cations" and "free acids" in toacco; 5. The gravimetric determination of nictine; 6. The chemical composition of Bulgarian obacco; 7. Textbooks for agricultural colleges n inorganic, organic and agronomic chemistry, nd others. Important scientific work has been one by Docent E. Levenson in determining the utrient requirements of the principal soil types f Bulgaria (9, 10).

At present the Department of Agricultural hemistry of the Sofiya Agricultural Institute s carrying out some large-scale work of great nportance for agriculture, including the followng projects: 1. Biochemical investigations of he sunflower, *Phaseolus* spp., vegetable crops, ugar beets, and other crops as related to the se of fertilizers on the principal soils of Bularia; 2. The use of straw as fertilizer, both in ts original form and also as composts with ineral fertilizers; 3. A study of systems of ertilizers on cooperatives; 4. The production f "biogas" (methane) from manure with the se of anaerobic enzymes; 5. Working out methds for the determination of available forms f nitrogen, phosphorus, and potassium which re applicable to Bulgarian soils.

The Department of Agricultural Chemistry of Plovdiv Agricultural Institute is younger and lid not become an independent department unil 1950. Since 1953 the Department of Agriculural Chemistry has been headed by Docent Lazar Stanchev. At present its scientific work leals with the following questions: 1. A study of the effectiveness of green manures in orchards without irrigation (annuals: blue lupine, winter peas, winter vetch with oats, black and white mustard, vetchling and fall-plowed fallow)—the esults of the experiments showed that the best mprovement of soil was given by black and white mustard, followed by annual blue lupine; . A study of the effect of annual and perennial rasses and grass mixtures (alfalfa, tall meadow oats, meadowgrass, orchardgrass, timothy, red lover, sainfoin, Sudangrass, and vetch) on the ertility of the soil and the harvest of agriculural crops (11); 3. Composting bone flour with organic fertilizers; 4. Methods of preparng artificial manure; 5. The effect of physioogically acid mineral fertilizers, manure and acid soils on the solubility of bone flour; 6. A study of trace elements in the soils of southern Bulgaria; 7. The effect of fertilizers on the quality of the fruit and the prevention of periodic fruit-bearing in quinces; 8. The agricultural chemical characteristics of types of soils in the areas of Plovdiv and Asenovgrad on which the "Marvut" variety of grapes is grown.

Further, we learned of work with fertilizers in a number of branch scientific research institutes and experimental stations.

The Scientific Research Institute for Cotton Raising of the Ministry of Agriculture, founded in 1925 at Chirpan, also merits our attention. At this Institute there is an experimental tract of 420 hectares on which four separate crop rotations are maintained, two of them four-field types and two eight-field. Experiments on the following questions are being carried out by the Division of Agricultural Engineering and Fertilizers: 1. The action of various quantities of manure on the cotton crop (10, 20, 30 and 40 metric tons per hectare); 2. Soil nutrient requirements for eight-field crop rotations; 3. A study of the effect of foliar application of 0.1 to 0.2% solutions of NPK fertilizer. In the basic field experiments which were carried out on soil nutrient requirements it was established that cotton is most responsive to phosphorus in quantities of 80 to 90 kilograms per hectare of P_2O_5. Nitrogen has no action on it. The action of potassium is restricted to the fibers, except on the ordinary chernozems in Gorodishche (Northern Bulgaria), where it exerts a positive effect on the total crop. The study of the quantity of manure (10, 20, 30 and 40 metric tons per hectare) showed that manure has the best action in quantities of 20 to 30 metric tons per hectare when applied under the fall plowing. The best action on the cotton crop is exerted by the simultaneous application of manure with mineral fertilizers. For large-scale application under cotton, they recommend the use of 20 metric tons per hectare of manure with two or three centners of superphosphate.

The Scientific Research Institute for Tobacco Raising was founded in 1950 in Plovdiv with an experimental network in the basic tobacco-raising regions. Of greatest interest from the standpoint of production were recent field experiments in studying the effect of various forms of nitrogeneous fertilizers (ammonium nitrate, ammonium sulfate and urea) on the tobacco crop with various methods of application: by applying the whole amount before planting; or by applying one half of the quantity at planting and the other half after the second cultivating as a supplemental feeding between rows. The amount was 30 kilograms per hectare of N. In experiments tobacco was most responsive to ammonium nitrate and urea.

Nitrogen-phosphorus fertilizers proved to be most effective in the ratio of 1:2, respectively. Positive action of potassium fertilizers develops when they are applied with organomineral mixtures or with large quantities of nitrogen-phosphorus fertilizers.

Promising fertilizers for tobacco are the green manures. In 1952 on the experimental tract at Gotsedelchev Dimitrii Shibanov established the high effectiveness on the tobacco crop of lupine and spring vetch sown in the fall or early spring. Green manure increased the tobacco crop by up to 5 centners per hectare. Under large-scale tobacco sowings they use ammonium nitrate at one centner per hectare and granulated superphosphate at 1.5 centners per hectare. In place of these fertilizers, rotted manure (three metric tons per hectare) and powdered superphosphate (2 to 2.5 centners per hectare) may be applied for two or three years.

Important work in the study of the effect of fertilizers on the yield of vegetable crops, sugar beets and rice is being carried out by the "Maritsa" Scientific Research Institute for Vegetable Growing founded in 1930 on rice fields near Plovdiv. They now have an experimental tract of 400 hectares on which 26 crop rotations are maintained. The soil is meadow cinnamon-brown type (3, 5, 7, 12, 13, 15). Local and mineral fertilizers are at present widely used under vegetable crops.

The Institute makes the following recommendations for the use of fertilizers under different crops: *Tomatoes* respond well to "nitrofoska"[2] in quantities of four to five centners per hectare applied three times as a supplement before picking the first fruits. When planning crops of 100 to 120 metric tons per hectare, they recommend application of five to six metric tons per hectare of liquid manure with humus two or three times with irrigation floodings jointly with the application of mineral fertilizers. *Cabbage* is fertilized by full mineral fertilizer $N_{60}P_{120}K_{60}$ applied three times as a supplement when planning a crop of not less than 500 cen ners per hectare. *Onions* are given $N_{60}K_{120}$ three supplementary applications before t bulbs are formed. *Peppers* react well to calciu nitrate in quantities of three centners per he tare and superphosphate at three to four cen ners per hectare. These fertilizers are applie as supplements at three different times. Fert lized crops yield up to 500 centners per hectar unfertilized 380 to 400. *Cucumbers* withou manure respond well to four centners per he tare of ammonium nitrate. If manure is applie at 40 metric tons per hectare as a supplemen only 1.5 to 2 centners per hectare of ammoniu nitrate is used and a crop of 250 to 300 centne per hectare can be expected. Irrigated *suga beets* respond well to full mineral fertilizer applied in four batches as $N_{100}P_{60}K_{75}$: one thir of the phosphorus and potassium is applie under the fall plowing; another third of th phosphorus and potassium is applied durin tillage just before sowing; the remainder, plus th nitrogen, is applied as a supplement in tw batches. With such a system of fertilizers suga beet crops of 600 to 700 centners per hectare ar produced as opposed to 300 to 350 without fertilizers. The Water and Soil Improvement an Agricultural Experiment Station at Pavliken (19) recommends applying under sugar beets grown on thin chernozem with abundant vertical filtration a full mineral fertilizer in three batches of $N_{35}P_{90}K_{60}$: in autumn $P_{45}K_{30}$ under deep plowing; $N_{15}P_{45}K_{80}$ under cultivation; and N_{2} as a supplement with the second cultivation. Given as supplements, phosphorus-potassium fertilizers do not exert a positive action. On agricultural labor cooperatives, 30 to 50 metric tons per hectare of manure is applied under the fall plowing for growing sugar beets.

For fertilizing *rice,* the best method is applying a supplement of four centners per hectare of ammonium sulfate plus five to six centners per hectare of superphosphate. The average rice crop in experiments was 50 to 60 centners per hectare, as against 30 centners per hectare without fertilizing. The rice crop under large-scale conditions averages 38 to 40 centners per hectare.

Many experimental institutions in Bulgaria have been carrying on studies of the action of fertilizers on grain crops (winter wheat, winter barley, oats, corn, spring wheat and others). The greatest number of field experiments in determining the soil nutrient requirements of winter wheat, oats, vetch-oats mixtures, and sugar beets has been carried out by the oldest agricultural experiment station, the "Model Farm" in Ruse (founded in 1922) (5, 8), and also at the Composite Agricultural Research Institute in Knezh (founded in 1925), at the Vylko Chervenkov Agricultural Research Institute in Dobrudja (8), at the Agricultural Experiment Station in Pavliken (19), and at certain other institutions.

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[2] Nitrofoska is a graded series of fertilizers consisting usually of fused ammonium nitrate and phosphate with potassium chloride and sometimes potassium sulfate—Translator.

The nutritive requirements of the main soil types of Bulgaria have been clarified by the work of E. Levenson and A. Kitipov (9, 10) using soil samples collected by the Soviet-Bulgarian soil expedition in 1947 (1) to set up growing experiments.

The data which we assembled from many years of growing experiments showed the greatest response by agricultural crops to nitrogen and phosphorus both when applied separately and together. Winter wheat on all soil varieties develops the greatest requirement for phosphorus. Winter barley on meadow cinnamon-brown soil is most responsive to NP and on typical chernozem to phosphorus. Oats on gray forest soil are most responsive to nitrogen and on leached chernozem to NP. Corn gives its greatest reaction to phosphorus. Sugar beets respond to nitrogen, PK and NPK. Sunflower responds to NP, PK and NPK.

Generalizing the results from the experimental institutions and data of the leading practitioners makes it possible to come to the conclusion that most of the soils of Bulgaria need nitrogen and phosphorus. The question of potassium nutrition is third in importance. With a rise in the level of agricultural practices and with increases in the crops of technical plants (chiefly tobacco, sugar beets and cotton), fruits and vegetables, the importance of potassium fertilizers will become continuously greater. The role of potassium will also increase with combined application of all the elements of nutrition.

Scientific research institutions have devoted a great deal of attention during the past five-year period to granulated fertilizers (chiefly superphosphate) and to organomineral mixtures.

The results of experiments carried out for this purpose have given evidence of the strong positive effect of granulated superphosphate applied with the seeds in rows on the crop of winter wheat, sugar beets, sunflower and corn.

The results of experiments in applying organic fertilizers combined with mineral fertilizers show their great effectiveness for a number of agricultural crops and under various combinations of soil and natural conditions.

All scientific work on orchards is concentrated at the Scientific Research Institute for Fruit Culture, founded in 1950 at Plovdiv. Along agricultural chemical lines, the Institute is studying the effect of organic and mineral fertilizers on fruit trees in order to do away with periodicity. For maintenance, superphosphate at 90 kilograms per hectare of P_2O_5 and potassium sulfate at 90 kilograms per hectare of P_2O is applied every year. After a year 20 metric tons of manure is applied per hectare. In experiments with fertilizers the apple crop was not less than 100 centners per hectare, the highest yield being up to 800 centners per hectare. The crops of pears and apricots in young orchards amounted to 200 to 300 centners per hectare; in old orchards crops amounted up to 700 centners per hectare. From 1950 to 1953 the experimental station of the Institute of Fruit Culture at Plovdiv (17) carried out experiments on fertilizing the "Madam Muta" variety of strawberries which showed the greatest effectiveness by rotted manure at 10 metric tons per hectare combined with $N_{30}P_{45}K_{45}$. A study of the effect of fertilizers on the grape crop by the Scientific Research Institute for Grape Culture at Pleven began only in 1954. This Institute recommends applying in the vineyards 20 metric tons per hectare of manure in the fall under the plowed land, and mineral fertilizers in spring before the growing season (ammonium sulfate, two to six centners per hectare, superphosphate three to six centners per hectare, and potassium sulfate, two centners per hectare.)

The Scientific Research Experimental Station for Volatile Oil Plants, founded in 1921 at Kazanlyk, is studying the action of fertilizers on irrigated rose-growing plantations.

The total quantity of mineral fertilizers used in Bulgaria in 1955 amounted to 1,141,000 metric tons and in 1956 to 1,320,000 metric tons. The fertilized area amounted to 830,000 hectares.

The greatest amount of nitrogen fertilizers was applied under early tomatoes, rice and potatoes; the greatest amount of phosphorus fertilizers was applied under early tomatoes, cotton and sugar beets.

With increasing use of fertilizers in Bulgaria an increase is taking place in the productivity of the basic agricultural crops. The productivity is steadily rising on the fields of agricultural labor cooperatives. According to data from the Ministry of Agriculture of Bulgaria, the productivity of agricultural labor cooperatives for 1955 is expressed on the whole for the country in the following figures: wheat, 15.9 centners per hectare; corn, 23.7; sunflower, 13.6; and barley, 18.8. This is half again as great as the average productivity in the old Bulgaria.

In the next five-year period (by 1960) production and delivery of twice as much mineral fertilizer is planned as in 1955. The basic fertilizers for Bulgarian agriculture will be superphosphate and ammonium nitrate.

In the system of agricultural measures, the Bulgarian Ministry of Agriculture has devoted much attention to the maximal use of all local fertilizers. Use of about 12,000,000 tons of local fertilizers is planned for the People's Republic of Bulgaria for 1955 and 1956. By 1960 the use is planned of up to 20,500,000 metric tons (corresponding to the yearly application of 4.3 metric tons per hectare) of manure, liquid manure, dung, feces, peat, ashes, and composts. Using these quantities of local fertilizers on five-field crop rotations makes possible the yearly application of fertilizer to one field at the rate of 20 metric tons per hectare.

Some great tasks lie ahead of the science of agricultural chemistry and the practice of agriculture in Bulgaria. In the immediate future they must study, introduce, or decide a number of questions related to the introduction into practice of new measures for applying chemistry in agriculture. The developing fertilizer industry should turn its attention to the production of the more highly concentrated fertilizers: urea, liquid nitrogen fertilizers, double superphosphates, ammofos[3], di-ammofos, and potassium chloride, sulfate and nitrate.

The science of agricultural chemistry should more widely include in scientific research institutions the working out of fertilizer systems for actual crop rotations depending on the complex of soil and climatic conditions. It should also include the study of green manures and bacterial fertilizers, trace elements, foliar application, local fertilizers, the technique of applying fertilizers, and a number of other questions.

Bulgarian agriculture is faced with the problems of accumulating a large quantity of local fertilizers, of building manure storage places and warehouses for storing mineral fertilizers, and of working out plans for the application of chemistry and systems of fertilizing in agricultural cooperatives and state farms. We hope that Bulgarian agriculture, under the leadership of the Communist Party, the Agricultural Union and the Government of the Fatherland Front will master these outstanding problems in the next few years.

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[3] Ammonium dihydrogen phosphate—Translator.

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